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A Content Validation Study of Performance Standards Application in Technical Skills Education

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A Content Validation Study of Performance Standards Application in Technical Skills Education

by

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VITA

The author, John Joseph Gammuto, is the son of Philip D. and Mary (Elia) Gammuto. He was born January 7, 1925 in Chicago, Illinois.

His elementary education was obtained in the public schools of Westmont, Illinois and secondary education at the Downers Grove Community High School, Downers Grove, Illinois, where he graduated in 1943.

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CHAPTER I

INTRODUCTION

Industry has attempted to address the need for improved training programs in advanced technical skills. The complexity of equipment, increased regulatory requirements, and advanced technical demands have all contributed to the need for change. Many problems of industry deal with the human factors of performance and competency levels of the work force. The human factors issue deals specifically with the relationship of systems design, equipment and the people who perform the tasks associated with the work environment.

Political forces in the form of environmentalists have exerted pressures on all industries that affect the environment. Industry has responded to these influences by addressing the issues of self-improvement and establishing new guidelines to achieve credibility in providing safe and economical services to the public domain.

In the past decade, the field of technical skills training, especially in the electric utility industry, has concentrated on a systematic approach to program development. With the complexities of nuclear power plants and the vast amount of human performance data to be collected and analyzed, a systems approach has offered the greatest advantages. The most significant contribution to organizing and developing systematic training programs in industry was provided by authoritative experts in the academic community. The works of Tyler (1949), Bloom (1956), and Mager (1962), provide a structural framework for designing and evaluating educational programs using the behavioral objectives approach within a systems context.

Purpose of Research

The purpose of this research is to explore the various aspects of educational program design through a review of the literature pertaining to content validation of educational learning systems. The generic information obtained in the review provides a data base for translating an academic methodology to an industrial application of training program validation. The specific aim of this research is to satisfy the need for performing validation studies that are applicable to training programs in industry.

The need for validation research is more important than ever since the accident reported at Three Mile Island Nuclear Station located near Harrisburg, Pennsylvania. The follow-up investigation and ensuing Kemeny Commission Report (1979) found that human error contributed significantly to the events which took place at Three Mile Island. The fear generated by the experience is not the only impetus for a more rigorous content validation of personnel training programs. Every year industry spends millions of dollars on industrial training. All too often there is little data to support huge capital expenditures. Cost-benefit of programs and a competent staff become a must to help insure that training is successful in the industry.

The training responsibility is becoming increasingly complex in terms of technology, program development, evaluation, and documentation of the learning process. The problems associated with learning systems and training organization are generic to most industries. The commonality of basic needs in most training organizations indicates that a more systematic and theoretically sound approach would provide greater benefits and aid the organization in adapting and reacting properly. The nuclear power industry was provided a cause of concern within government and private agencies for improved performance in safety and plant reliability.

The primary concern of governmental agencies, as well as concerned citizen's groups, begins with improving the safety aspects of nuclear plant operation. The competency of the work force is a major factor in determining risk associated with safe operation. Unskilled personnel, human error, and the attitudes of management have served to promote poor performance and unsafe practices (Kemeny Commission Report, 1979).

The problems of program development and validation include many contributing factors. The success or failure of program development and its implementation is dependent on the competency of the training staff. Most industrial trainers are assigned from the production ranks of plant operations and maintenance groups. They are selected according to the criteria of availability and communication skills. The critical skills of instruction, program design, evaluation techniques, and administration are not emphasized in most industrial training organizations. Following the Kemeny Commission Report, the credibility of training organizations within the nuclear power industry has been questioned internally as well as externally by governmental and private interests.

Most recently, a plan for establishing certification and documentation of acceptable performance standards for instructional staffs has been proposed by the Institute of Nuclear Power Operations (INPO). INPO is a newly formed organization sponsored by member utilities who own and operate nuclear power facilities in the United States. The INPO organization has the primary responsibility of assessing the needs of the sponsoring utilities and establishing benchmarks of excellence for the safe and reliable operation of nuclear plant facilities. The formation of INPO and additional governmental regulatory requirements further emphasize the need for the validation of present and future training programs.

For purposes of application, the research activities focus on the training programs conducted at nuclear power plant facilities and centralized training centers located within the Commonwealth Edison Company system. The selection of the Commonwealth Edison Company provided several benefits to the researcher. The Commonwealth Edison Company is identified as a leader in the nuclear power industry. The pioneering of nuclear power at Edison has become history in the power industry. The Edison system is representative of any major electric utility company in the United States. Another benefit of selecting the Edison system was the convenience of research activities. The accessibility of research data was eased by internal cooperation of the corporate training organization and plant managers. Although a large portion of the research study was dependent on activities located in a central training facility; additional data was collected from each selected plant location for verification.

The central training facility known as the Shorewood Training Center located in Joliet, Illinois provided a primary learning experience in keeping tools, equipment, and systems in the generating plants in peak condition. The site of this study is part of the training program provided by the Commonwealth Edison Company.

The Mechanical Maintenance Program for "B" Mechanics conducted at Shorewood is structured on a systems approach to learning activities (Mager, 1962). Trainees study theory, learn basics, and work with a variety of learning materials associated with their job assignments. At the same time, trainees become familiar with actual equipment and systems in hands-on situations that give reality and practicality to theory-related knowledge levels in assigned job positions.

This study focuses on the validation of one position in the nuclear stations rather than an attempt to validate training programs for all generating station positions throughout the company's systems. This provides a model for the industry by studying one position in a specific work classification. The particular job was selected after conferring with both station and training personnel at various company locations.

Definitions

The following definition of terms shall be used for the purposes of this study:

"B"-man shall be used to refer to the "B"-man position in the Mechanical Maintenance group at Edison stations. It is the mid-classification for performing maintenance tasks. The "B"-man is not considered a full-fledged craftsman until he is able to perform all functions of Mechanical Maintenance assigned at the work location. As a comparison to academia, he is a sophomore or junior as related to a graduate of a specified degree program.

Content validity shall be used to refer to the extent to which the content of the training experience is covered by the evaluation measures used to monitor students' progress.

Criterion measure shall be used to refer to a standard on which a judgment can be based concerning human performance.

Learning hierarchy shall be used to refer to a set of specific intellectual capabilities having an ordered relationship to each other, which functions in a horizontal manner.

Performance test shall be used to refer to any measure either written or orally administered which seeks to determine a person's mastery of a critical job behavior.

Predictive validity shall be used to refer to the skills tested and a logical relation between the tests and job elements reflected in the criterion measure.

Reliability shall be used to refer to the consistency of the performance measures in two ways: (1) over time and (2) as assessed by different observers.

CHAPTER II

REVIEW OF LITERATURE

Introduction

A review of the literature reveals numerous studies keyed to the evaluation and validation of academic programs. With a view of the future, the same information can be transformed to an industrial application of validating training programs. In the industrial application, program worth and effectiveness are essential considering the cost/benefit inquiry of corporate managers. The justification of cost becomes a major issue in the determination of worth according to Bunker and Cohen (1978, pp. 4-11). The potpourri of significant concerns in the training process deals mainly with the issues of cost effectiveness and the prescription for improving the training program to meet the needs of the target population and validate the process.

The question of internal validity becomes an issue considering the political ramifications of big business. The quality and design of validating training programs has major significance when considering worth and cost effectiveness. The reliability of data for validation and justification of time and expenditures requires specific objectives to satisfy vested interests involved in the validation process (Brown and Sommersville, 1977, pp. 28-46).

Although there are many forms of validity, the three main types are: content validity, criterion validity, and construct validity (Anastasi, 1969, pp. 134-161). Anastasi considers these types of validity mainly in terms of psychological tests, and they can also be usefully applied to methods of performance evaluation and validation. According to Anastasi, content validity is the extent to which the totality of the content of the learning is covered by the evaluation measure. Tyler (1949, pp. 11-12) amplifies this definition by adding the importance of the evaluation measure being representative of the stated objectives. Tyler's work has influenced the behavioral objectives approach in both academia and industry.

Theories of Instruction

Tyler provided a better understanding of individual needs in the learning process. This view is now recognized by others who have adapted the system to fit their needs. Jerome Bruner's theory of instruction (1966) provided a practical needs assessment of shaping instructional growth. The individual differences in learners and learning are described most effectively by Tyler (1949), Bruner (1966), and Bloom (1976). Their studies influenced further research applicable to developing and validating individual performance using an objectives approach to the learning process.

Early in 1962, Mager provided a system of identifying behavioral objectives. His system simplified the writing of behavioral objectives related to the tasks to be learned. The systemized listing of sequential events using the behavioral objectives approach provides a data base for performance standards and validation. Mager's further studies provided a means for measuring instructional intent (Mager, 1973, p. 15). The matching of performance and the conditions of the test items with those of the objectives requires an ability to decode objectives by identifying the characteristics within the objective and determining whether a test item is suitable for assessing the achievement of an objective (Mager, 1973, p. 16). A suitable test item matches the objective in performance and conditions.

Goldstein's model of an instructional system (1974) involves three phases: assessment, training and development, and evaluation. Typically instructional systems models are based on similar processes such as assessment, program implementation, and evaluation. This concept may not be universally acceptable; the conditions of specific applications dictate the design of effective training programs.

Instructional Systems Design

The development of an instructional system involves a series of procedures. The steps in development derive from a variety of sources (Gagne, 1974, pp. 209-229). The general steps described by Gagne are listed as follows:

- Analysis and identification of needs
- Definition of goals and objectives
- Identification of alternative ways to meet needs
- Design of system components
- Analysis of (a) resources required, (b) resources available, (c) constraints
- Selection or development of instructional materials
- Design of student assessment procedures
- Field testing: formative evaluation and teacher training
- Adjustments, revisions, and further evaluation
- Summative evaluation
- Operational installation.

According to Gagne (1974) the major advantage of this system is that it encourages the setting of a design objective. The evaluation of a system provides an assessment of training outcomes and the effects of instruction, which includes unanticipated outcomes. Performance criteria are based on behavioral objectives that are determined in the assessment phase. The criteria are standards of performance that describe the behavior required for successful achievement of the training objectives.

Evaluation Design

How performance is measured is determined by the evaluation design, which includes the measures and procedures to be used (Kirkpatrick, 1975, pp. 1-13). Kirkpatrick describes the techniques for evaluating training programs in four steps. The four steps include the categories of reaction, learning, behavior, and results.

Reaction measures the attitudes of program participation. It may tell you nothing about the effectiveness of the program. It simply tells you about its acceptance. Generally, a reaction sheet is prepared, with a structure that facilitates tabulation and statistical analysis; but it should include some open-ended questions. This method is frequently used to evaluate training in industry because of its simplicity in application.

Learning is more complicated, and it reveals whether the information has been transmitted and performance levels have been improved. Validation procedures require a fairly high level of sophistication in the analysis of performance levels of competence. Behavior evaluation purports to measure on-the-job changes in behavior in relation to a given standard. It is not used extensively in industry, principally because it is difficult to develop and time consuming. Although some standardized measuring instruments are available, training directors usually find it necessary to develop their own devices for observing, recording, and measuring changes in behavior.

Results are the corporate payoff of all training activity. The results that an organization looks for are cost/benefit documentation. Training programs can contribute to a reduction in human error; improved decision making; and a reduction in employee turnover, labor costs, and the number of grievances. This type of evaluation is not carried out often because of problems in controlling extraneous variables. In other words, the results may not be attributable to the training program (Kirkpatrick, 1975).

An effective program requires the systems approach to evaluation and validation procedures (Hale, 1980). The systems approach to validating programs includes the following essentials:

- Perform a job analysis
- Identify performance tasks of the job
- Develop criteria of performance
- Determine the research design
- Collect the data
- Analyze the data
- Interpret the results
- Revise the program as needed.

Validation procedures are usually discussed in relation to tests because test scores are quantitative and therefore lend themselves readily to statistical analysis

(Anastasia, 1968, pp. 28-29). The determination of validity requires independent external criteria applicable to determining the validity of program effectiveness and performance standards. The validation of training materials requires the conversion of data and judgments into numerical form.

The works of Robert Mager have influenced industrial training significantly. Mager's publications are recognized as an effective means of providing job-related training that results in improved performance. His approach translates job requirements into behavioral terms (Mager, 1962, p. 13). The needs contained within the job assignment are seen as indicators of the tasks associated with effective job performance.

Through observation, interviews, and a review of training manuals, the job analysis provides answers to the following questions (Science Research Associates, 1972):

- What initial skills or knowledge must the worker possess?
- What skills and knowledge is he expected to gain during the training?
- What physical and perceptual attributes are required by the tasks?
- What mental abilities and aptitudes are needed?
- What personal attributes are necessary?

Following the job definition, the process of identifying specific tasks to be performed is needed to formulate the behavioral specifications known as objectives.

Task Analysis

Pipe (1975, pp. 36-42) describes a task as a meaningful unit of work activity, generally performed on the job by one worker within some limited period of time. It is a purposeful job-oriented activity of a worker.

Each task performed by workers in an occupation should be a logically differentiated segment of the work activity. In content, a "task" is generally described as a job activity that is intermediate in specificity between a "function or responsibility" and a "procedural work step or action." It is a discrete unit of activity and represents a composite of methods, procedures, and techniques which commonly serve to accomplish one meaningful unit of work. Tasks involve worker interaction with such objects and elements as equipment, material, other people events, and conditions. In most instances, the performance of a task by a worker has a reasonably definite beginning and end.

For use in occupational surveys and curriculum design, statements of tasks should have a certain grammatical structure and conform to several characteristics.

Brevity and clarity are the foremost considerations (Ammerman, p. 22).

Each statement of a task is composed of three basic elements:

- A specific action verb, descriptive of what is done
- A brief identification of what is being acted upon (the object of the action verb)
- Whatever qualifying phrases may be needed to clearly distinguish the task from related or similar activities, or to limit and define the scope of concern.

For use in the process of making decisions about appropriate job content, it is also necessary that task statements be specific and reflect only one meaningful unit of work activity. Where the use of the statement is not for making curriculum content decisions, but to aid in differentiating between types or levels of workers in an occupational field, then some broader statements of work activity may be adequate.

Each task statement should conform to the following guidelines:

- Grammatical conformity (It includes format, verb, and grammatical content.)
- Performance specificity (represents a distinct piece of work done by the work of a specific

work group.)

- Generally used terms (Task should be stated using technical terminology that is consistent with current usage in the work group.)
- Job-oriented activity (Describe what gets done by a worker in job-oriented task statements.)

Behavioral Objectives

According to Zais (1976, p. 306), curriculum objectives are defined as immediate specific outcomes of instruction. Cronbach (1949) refers to objectives as related to what the participants will be able to do and the degree of performance.

Bloom's taxonomy of educational objectives is divided into three principle domains: cognitive, affective, and psychomotor. The cognitive domain includes those objectives which involve intellectual tasks (Bloom, 1956). Bloom describes the cognitive domain in six intellectual functions of mental abilities: (1) knowledge, (2) comprehension, (3) application, (4) analysis, (5) synthesis, and (6) evaluation. The intended arrangement of these functions was based on the idea that a simple behavior can be integrated with other simple behaviors to form a more complex behavior. An order of difficulty is established by following the mental ability functions in sequential steps (Zais, 1976, p. 309).

Another view held by Polanyi (1966) criticizes the behavioral objectives approach to program development. According to Polanyi, behavioral objectives do not consider "tacit knowing." He describes "tacit knowing as a knowledge that we may not be able to tell" (Polanyi, 1966, p. 4). Polanyi's findings question the validity of organizing statements for curriculum design into behavioral objectives.

Another criticism of behavioral objectives is the inherent weakness described as the logic of operationalism (Smith, 1962). The question of operational definitions may or may not restrict the meaning of objectives. While some objective lists are stated in terms that are more general than others, behavioral purists maintain that maximum specificity is necessary for ultimate clarity (Mager, 1962).

Assessment and Evaluations

The term assessment is often used interchangeably with the term evaluation. According to Anderson, Ball, and Murphy (1977, pp. 26-27) assessment has a narrower meaning than measurement. It therefore seems appropriate to limit the term assessment to the process of gathering the data and fashioning it into an interpretable form; judgments can then be made on the basis of assessment.

Assessment, as opposed to simple one-dimensional measurement, is frequently described as a multi-trait, multi-time method. That is, it focuses on a number of variables and techniques to produce raw data. The assessment approach helps to define a program of testing, data collection, and analysis that would permit the desired reporting for a validation study.

For discussion purposes, potential assessment program reports can be divided into three categories: (1) comparisons, (2) reports on specific performances, and (3) reports indicating the proportions of defined groups achieving specified standards for particular tasks or objectives or achieving minimal competency in the skills area (Anderson, Ball, and Murphy, 1977, p. 27).

Comparisons are usually made in assessment programs, regardless of level. The survey achievement tests used in many training programs permit normative comparisons. Norm-referenced testing and scoring are often used to set performance standards or criterion levels against which groups are compared (Popham, 1969, p. 4). These norm-referenced comparisons, however, are not based on the specifics of what trainees know or can do, but on relative performance on some generally defined collection.

The task sample approach to criterion referencing places great weight on the precise nature of the items and exercises used as a basis for judgments of mastery. The nature of criterion-referenced items developed for the cognitive areas of a reporting-by-objectives assessment program will require trainees to demonstrate competencies.

If a multiple choice format is used, the similarity of items is almost guaranteed. This outcome is particularly likely to occur in an assessment setting where the constraints of large-scale testing reduce the flexibility of the item developer. Other approaches to criterion-referenced testing can place less emphasis on the nature of the item development procedures and more on empirical validation (Ebel, 1971, p. 284).

One factor that suggests that a validation approach can be productive is the strong relationship that has been observed among many apparently diverse tasks. A conventional survey achievement test is likely to rank trainees in a manner very similar to the ordering produced by a criterion-referenced test composed of tasks specifically designed to sample a limited number of target behaviors (Harris and Stewart, 1971). When this is true, it is possible to make a criterion-related interpretation of performance if the basis for interpretation can be established empirically. Basically, the method suggested involves discovering the statistical relationship between test scores and another measure of the criterion interest. Using this relationship, criterion-referenced score reports for technically sophisticated groups can be either regression estimates, or criterion standing, or probability statements about individual's positions on the criterion based on an experience table (Popham, 1969).

The fact that validation procedures would lead to "estimates" and "probability" statements may make it appear that they would necessarily result in less precise information about competencies than would be obtained by the use of task or work sample tests. In this connection, it will be useful to consider that even a work sample approach to criterion-referencing requires an inference or estimate regarding an individual's probable performance on some population of tasks. The size of the work sample, moreover, is only one of the factors affecting the accuracy of the estimate. One of the advantages of the validation approach over the work sample approach is that the magnitude of the errors due to these sources can be estimated (Glaser and Nitko, 1971).

The principle obstacle to the validation of criterion-referenced items is that the suitable criterion measures are often not readily available, and thus need to be developed. One of the purposes of these measures is to suggest ways in which this might be done. When direct criterion measures are available, or are developed, it may be argued that there is no need to administer the test from which criterion-referenced inferences are to be drawn. In this connection, it should be noted that costly and time-consuming methods are perhaps best limited to only a sample of the total group. One would use a sample to determine the test criterion relationship and then use the test only to yield criterion-referenced scores for the remainder of the group.

In generating the criterion measures to which test scores will be referenced, the approach adopted will depend on the nature of the ultimate interpretations and decisions that will need to be made (Banathy, 1968). Suppose, for example, that the program developer wanted to estimate the proportion of trainees above and below some specified minimal competency level in a basic skills area. There may also be interest in obtaining a preliminary indication of which individual trainees are above or below this level. It will be assumed that for any given application, a suitable behavioral definition of minimal competency can be developed in the form of a limited set of basic and critical educational objectives. In developing the criterion then, one might provide a representative sample of instructors with appropriate training in the use of this definition as a basis for rating trainees. The instructors would then be asked to classify their trainees as above or below minimum competency by using performance-based tests.

In applying the method suggested here, both ratings and scores on the appropriate survey tests are collected for a sample of trainees. It is then a relatively simple matter to find the level of test performance that "best" discriminates between those trainees judged to be above and below the minimal competency level. A cutting score on the test could be selected which leads to the most correct classifications in the sample.

All of the foregoing discussion deals with the use of test validation procedures to overcome the limitations of task sample approaches to criterion referencing. Actually, the two approaches can be used concurrently. In some settings, the development of tests focused narrowly on particular objectives may be possible, and may serve as the basis for estimating group performance. It may be too costly or time-consuming, however, to administer each of these focused tests to each member of the group. In this situation, it may be considered more efficient to administer a limited number of broad range survey tests to all and use a select subject item and examine sampling design for the administration of the selected tests. The relationship of focused survey tests discovered in samples then allows criterion-referenced reporting for individual trainees of the survey test scores.

The idea has been advanced that criterion referencing may be approached as a problem of validating tests for particular inferences about human behavior. Several methods have been suggested for validating tests for making inferences to a particular criterion or to several criteria of interest. In each instance, the method carries with it the certainty of some degree of error that is associated with all measurement. It is suggested, therefore, that more than one method be used to validate any desired criterion-referenced inference (Anastasi, 1976, p. 140).

The most effective testing program is one that has met the needs of the trainee to perform his job. The post-mortem or evaluation is the instrument used to determine if these needs have been met according to the stated objectives at the beginning of the program. An assessment of what was accomplished can be determined in an evaluation of test scores recorded prior to instruction and immediately following the instructional period.

The question answered by such information reveals what changes have occurred as a result of training. Results evaluation requires concrete evidence that the training actually increased performance skills or produced other improvements related to the work activity being measured. Effective pre- and post-testing programs provide the documented evidence of performance skills levels if they are properly developed and administered.

Analysis of Performance

Few people would argue with the statement that managers are more successful in solving machine and systems problems than in solving problems involving human performance. Part of this lack of success can be attributed to the complexity, unpredictability, and general uniqueness of human beings. A major part of our failure at solving problems, however, is our failure to analyze these problems completely before we try to solve them. If we were more effective at analyzing people problems, we could significantly reduce the number of such problems.

There are several factors that contribute to our lack of success in analyzing human performance problems. First, when people are involved, we react to our biases or assumptions about human nature. Second, we are led by all the training courses and programs available to separate human performance problems from the complex environment in which they occur. We assume the cause and solution of the problems are completely wrapped up with the individual, and the problems or their solutions are in no way influenced by unclear standards.

According to some, there is really no useful operational way for the manager to analyze performance problems, though there are some interesting theories. Perhaps it is more comfortable for a supervisor to visualize a problem performer's "hierarchy of needs"; but it doesn't help him to solve the problem. Such theories may be useful to corporate staffs, who can design policies and procedures sensitive to what are supposedly "satisfiers" and "dissatisfiers," but understanding people at some abstract level is a long way from solving performance problems, as most educators know.

In training, we should be concerned with a viewpoint for analyzing performance problems. The following provides a framework for examining performance problems. An integral part of this approach is to examine the performer in his environment, concentrating on the relationship between the performer and his environment.

For the most part, human performance deficiencies can be classified as "deficiencies of knowledge," which result from an employee's not knowing what to do, how to do it, or when to do it; or as "deficiencies of execution," which result from an employee failing to perform because of factors in the work environment; or as some combination of the two (Rummler, 1972).

The distinction between deficiencies of knowledge and execution is considered a critical step in analyzing performance problems. A failure to measure this distinction accurately can result in prolonged, extended, and extensive training being conducted to solve an alleged knowledge problem that is in fact a non-training problem. In addition, such training tends to reduce the credibility of the training function, and frequently leaves management with the dangerous illusion that the performance problem in question is being solved.

The critical distinction between a deficiency of execution and a deficiency of knowledge can usually be made by getting the answers to these questions.

- What is the desired performance (job outcome)?
- What are the job standards?
- Does everybody agree on those standards?
- What are the specific performance differences between actual and expected performance?
- Could employees perform properly if their lives depended on it?
- Do employees whose performance is deficient know what is expected of them?
- What positive/negative consequences of performing correctly/incorrectly can employees expect?
- From their bosses?
- From their subordinates?
- From their peers?

Deficiencies of execution, or the failure to exhibit learned behavior on the job, can further be classified as resulting from the lack of feedback, task interference, lack of tools, unfavorable consequences or no incentive for performance (Mager and Pipe, 1970).

It follows, then, that proper management of consequences is critical in maintaining desired performance. The frequent, random, and arbitrary consequences that naturally occur in the organization must be brought into control, balanced, and managed in a way to support the desired performance.

Learning Hierarchies

The basic premise of learning hierarchies is that the ability to perform a class of tasks cannot be acquired unless all of a set of relevant subordinate skills, or elements of knowledge, are already possessed by the learner (Gagne, 1962, 1970; Gagne and Paradise, 1961).

According to Gagne (1968), a learning hierarchy is a "set of specified intellectual capabilities having an ordered relationship to each other." Each step in a learning hierarchy provides a statement of a performance to be demonstrated by a learner. To use the current terminology, the intellectual capabilities of the learner are reflected in performance or behavioral objectives. The ordered relationship of performances is reflective of Gagne's theory that subordinate tasks should be learned first to facilitate learning higher tasks (Gagne, 1970).

A modern approach to the notion that most students can learn what the instructor has to teach has been termed "mastery learning" (Bloom, 1976). There are many versions of mastery learning in existence (Bloom, 1976; Block, 1971; Keller, 1968). All begin with a notion that most students can attain a high level of learning capability if instruction is approached systematically and the learner is given adequate time and help when needed (Bloom, 1976).

Carroll's Model of School Learning (1963) suggests that if students are normally distributed according to aptitude, and are given exactly the same instructions, achievement by the entire group would be normally distributed. The correlation of gain between the beginning and end of instruction would be considered relatively high. Conversely, if the students are normally distributed with respect to aptitude, but the quality of instruction and learning time allowed are considerate of the needs of each learner, the majority of the group would achieve mastery and the achievement of each learner would approach perfection.

This improvement of achievement is supported by Block (1971). According to Block, there is considerable evidence that mastery learning techniques under specific conditions far exceed the non-mastery conditions of learning. Unfortunately, the norm in the electric utility industry is not compatible with Carroll's normal distribution of learners according to aptitude.

The aptitude level of learners and learning time allowed for each individual according to need is not a major factor in the selection of the participants for instruction. The selection process and time costs for training programs become less significant when the pressures of contractual agreements and regulatory requirements dictate a list of consequences of non-compliance.

Time costs for mastery versus non-mastery methods are typically 10 to 20 percent higher. This increase of time is attributed to the time required for diagnostic-progress testing. The process of diagnostic-progress testing provides a formative evaluation for corrective purposes. Prescriptive correctors are identified in the diagnostic-progress testing procedures as determiners of the treatment needed for improved performance.

A more comprehensive study of the mastery learning approach is described in Keller's Personalized Instruction Study (Block and Burns, 1976). In Keller's system, each student is expected to master each learning task before going on to the next. Each student proceeds at his own pace, and his achievement level is largely determined by the number of tasks he has completed and mastered. The Keller system has been used widely by college students, but only a few studies have been reported to substantiate its effectiveness.

The development and validation of learning hierarchies bear a close resemblance to the mastery learning theories of Bloom (1976) and Block (1971). The orderly sequencing of learning tasks according to difficulty levels, and the enforcement of intended terminal skills in accordance with behaviorally stated objectives, lend themselves to mastery of identified tasks and the validation process (White, 1974).

Learning hierarchies provide a strategy for planning and conducting formal instruction. A hierarchy of tasks leading to a selected terminal objective serves as an instructional map for teaching strategies. The instructional map provides a list of tasks to be accomplished by the learner as well as the sequence in which they should be learned and taught.

With a hierarchy and accompanying pre- and post-tests for each objective, an instructor can determine the initial performance of trainees. Armed with performance data from these tests, an instructor can start each trainee on the tasks in the hierarchy appropriate to his test performance (Fiel and Okey, 1975). Subsequent tests can be used to monitor the progress of individual trainees as they proceed in the training program. Trainees who demonstrate achievement can be moved on to higher tasks, while trainees who fail tests on objectives can be directed to restudy materials or drop back to earlier objectives (lower in hierarchy) that may have failed (Lindvall and Cox, 1969).

Developers of instruction are another group for whom learning hierarchies have potential value (Glaser, 1966; Briggs, 1970). Various systematic plans for development (e.g., Glaser, 1966; Briggs, 1970) invariably list a step in the development process which includes analyzing terminal tasks to establish a sequence of objectives. Curriculum development is aided by the sequencing of tasks after they have been identified.

A learning hierarchy, therefore, serves as a type of instructional blueprint in much the same way that a blueprint for a building aids the builder and his workers. The value of learning hierarchies is supported by research activities conducted by Walbesser and Carter (1968). Using an experimental science curriculum based on learning hierarchies, Walbesser and Carter reported nearly equal achievement among learners from various socio-economic levels. This equality suggests learning hierarchies are a useful method for establishing improved learning activities.

An additional use for learning hierarchies, according to Weigand (1970), is in researching the learning process itself. Weigand used a learning hierarchy to identify how intellectual development occurs in children. The sequencing of events in a step-by-step building block order provides a diagnostic test of progress in performance skills. This same technique also applies to adult learners.

In summary, learner performance is the final arbiter of correct sequencing and valid learning hierarchies. Evidence from the literature on learning hierarchies suggests that the improved performance of learners can be expected if validated learning hierarchies are used to facilitate a systematic approach to instruction. Of all the existing learning theories, instruction based on a validated learning hierarchy seems to have the potential of being most direct in its application to instructional systems.

Therefore, it becomes of interest to researchers to seek evidence of validity in the learning process (White, 1974).

Hypotheses

This study has been guided by two major hypotheses. These hypotheses have attempted to deal with the question of mastery in job-related skills using a sequential task-oriented systems approach to training program design and trainee performance.

Hypothesis 1: All trainees who have certain basic aptitudes can be taught to perform a particular industrial training skill.

Hypothesis 2: Training which requires individuals to show mastery of prerequisite skills before attempting mastery of job-related skills will be more effective than traditional industrial training which does not rely on sequential learning.

CHAPTER III

DESIGN AND METHODOLOGY

Introduction

This study is designed to follow a descriptive ex post facto method of defining internal and external validity issues in the design and methodology of training programs specifically in the electric utility industry. This study will attempt to determine a means of establishing a descriptive content validation of performance application resulting from a sequential process of training program design.

In the electric utility industrial setting, the need for direction in establishing a systems approach to formalized instruction has taken an added significance since the incident at Three Mile Island (Kemeny Commission Report, 1979). With the significance of establishing a revised approach to training personnel in the industry, the establishment of a documentary process to produce effective programs is both timely and cost effective.

The incident at Three Mile Island provides documented proof that the survival of the industry is dependent on the competency of the people who operate and maintain the plant facilities (Kemeny Commission Report, 1979).

The present research attempts to examine how to improve learning by establishing the degree of congruence between formalized learning conducted in a sequential order of events and the traditional non-sequential order of learning conducted prior to the last decade.

Objectives of the Descriptive Analysis

- To prepare a comprehensive list of task statements for the "B"-man position in the mechanical maintenance area.
- To collect ratings on the relative frequency of performance and perceived criticality of each of the defined task statements.
- To develop methods for evaluating acceptable performance standards for each highly rated task statement.
- To integrate such an evaluation system into standard operating procedures at the company's various on-line nuclear stations.

Description of the Population

The participants in this study were selected from three major locations in the Commonwealth Edison Company system. The participating locations were Dresden Nuclear Station, Zion Nuclear Station and Shorewood Training Center, Shorewood, Illinois. The research activities involving participants at these three sites were conducted in four phases. Phase I involved 30 participants. A sample of ten participants at each of the three sites were requested to complete the Task Inventory Questionnaire prepared by this researcher. The 30 participants represented supervisors, job incumbents, and the training staff at all three sites.

After the data collection procedures were completed, it was necessary to reduce the sample size by one and work with a N of 29. This was because one questionnaire was returned improperly filled out. As participants in this phase of research activities, the supervisors, job incumbents, and training staff were asked to review a list of task statements for the "B"-man position in the mechanical maintenance area. They were also asked to rate each task according to five dimensions of performance.

Phase II involved four members of the training staff at the Shorewood Training Center and this researcher. The research activities involved a group activity to analyze the data and determine the congruence between the task inventory and the training program objectives, content, and subsequent test items. This congruence was based on the cognitive taxonomy (Bloom, 1956). All objectives, task inventories, and test items were reviewed for taxonomy placement. The staff members involved had a combined total of 100 years maintenance teaching experience.

Phase III required three participants and this researcher. The objective of this phase was to evaluate the instructional methodology by conducting periodic observation visits to the classroom. The instrument for this evaluation was designed specifically for this research activity.

Phase IV involved 27 trainee participants. The purpose of this phase was to establish a descriptive internal validity of trainee performance. The use of pre-test and post-test evaluations provided documented test scores for the descriptive analysis of performance gain.

Collection of Data

The entire collection of data was done in six basic steps. The six steps were as follows for the researchers who:

- Conducted panel interviews with key personnel at three locations to collect task statements for the "B"-man position.
- Assembled those task statements into the form of a job inventory.
- Distributed the job inventory form to collect ratings on the "B"-man position at the three sites.
- Determined methods for evaluating acceptable performance standards.
- Prepared the actual evaluation instruments.

- Employed the evaluation instruments at appropriate times.

Job Analysis and Task Inventory

Subject matter experts were selected at each site to assemble task statements related to the job position. Each subject matter expert was interviewed for 90 minutes to two hours. The job elements for the "B"-man position were discussed at great length to establish a comprehensive list of task elements within the scope of assigned work activities for this position. The list of task elements was recorded in the form of a job inventory and rating system to determine congruence among the raters at the three sites selected.

The data for the task inventory were gathered through the use of a composite 20-page questionnaire which required raters to rate each of 27 separate task statements on five separate dimensions. (See Appendix A for a copy of the prepared Task Inventories.) The dimensions were described as follows:

Frequency (F): the extent to which a task is done or the amount of the "B"-man's time spent working on the task.

Criticality (C): the degree of importance of the task to the overall functioning of the power station.

Difficulty (D): the amount of knowledge or level of skill required to perform the task in an acceptable manner.

Safety (S): the degree to which performing the task creates a safety hazard or risk of danger for people or property.

Composite Measure (CM): the amount of attention to detail which is needed to perform the task when taking into consideration frequency, criticality, difficulty, and safety.

While the five dimensions were measured on a scale of 1 (low) to five (high) for each separate task, raters were also asked to check the skills which they felt were necessary for each of the 27 tasks listed in the questionnaire. A summary of means for each of the ratings, as well as the percentage of agreements for each of the skills, was recorded for future analysis.

Congruence of Task Inventory and the Training Program

The congruence between the task inventory and the raters established is what should appear in the training module content for instructional purposes. The high percentage of agreement among the 29 raters established a base for further analysis and program design. See Appendix A for a copy of the Task Inventory.

Congruence of Test Items With Training Module Objectives

The criterion for the selection of test items is how the test items relate to the stated objectives. A criterion test item is relevant if it reflects important elements of the desired job performance and total success on the job. The relevancy of a potential test item must be evaluated on a rational basis from a thorough knowledge of the total job and the expected measure of results.

Related to the question of relevancy is the problem of criterion test items that become contaminated. A common error in constructing an instrument to measure learner accomplishments is poorly designed test items. Faulty test item design will lead to inaccurate judgments about the value of potential predictors and intended outcomes. Successful performance has many dimensions and it becomes difficult to find a true measure of the original objective. The problem of finding a good measure of performance objectives is further complicated by the fact that many aspects of the desired performance cannot be readily measured objectively. Therefore, the congruence between test items and the training module objectives becomes dependent on relevancy, reliability, predictability, and desired outcomes or properly stated performance objectives.

In the work sample selected for this research a standard measure was established to determine the criteria of performance as related to the objectives. The work sample test items were selected according to performance objective statements and the task analysis items representative of the job classification.

The main advantage of relating the test items to the objectives is that the criteria of performance are consistent with intended outcomes. Second, the evaluation test items are administered under controlled conditions, and they present each trainee with the same problems. Such standardization increases the reliability of the data.

The procedure used in this research study dealt simply with selecting each evaluation test item and relating it to the stated performance objectives. See Appendix B for a congruence between objectives and test items.

Analysis of Instructional Methods

The analysis of instructional methods required the development of an evaluation instrument for measuring instructional and technical competencies. The immediate goal for designing an evaluation instrument was to provide a tryout of the instrument under actual training conditions. The data collected during the development phase enabled the researcher to outline the procedure needed to satisfactorily conduct and complete accurate, objective, and consistent evaluations.

Procedures

The pilot consisted of three phases.

Phase I: Schedule and meet with each instructor or staff member who would participate in the pilot. A pilot was conducted at each nuclear station site and the Shorewood Training Center.

Phase II: An evaluation team of the Program Development Staff and the Instructional Staff at each site were provided with instruction before using the evaluation instrument. Each participant collected data following the instruction using the Narrative Evaluation Guideline and Summary Evaluation Instrument. Written and oral critiques were given by each evaluator commenting on the Summary Evaluation Instrument's format, comprehensiveness, flexibility, and appropriateness to the industrial/occupational setting.

A post-observation conference was conducted immediately following each session to communicate the findings of the evaluators to the instructor. Feedback from the instructor was solicited at the conclusion of each conference to enable an assessment of effectiveness of the post-observation conference and how best to conduct it. This analysis aided in the development of the evaluation instrument guidelines.

Phase III: At the completion of Phase II all data from each observation were analyzed. The analysis set the stage for the review and consultation of the Production Department Training Staff, provided a basis for establishing statistical studies, and summarized the conclusions for obtaining qualitative data. The results of the pilot study for developing an instrument for evaluating instructional methods provided the format for reporting and documenting the specifics of instructional management conducted in the classroom.

Instructional Analysis Report

The analysis of instructional methods consisted of an Instructional Observation Report. The report was designed to identify eight specific categories of instructional management. Each category listed the desirable performance of the instructor as well as the degree of involvement of the learner.

The assessment of the instructor's teaching style was rated on a scale of 0-5. The high value of 5 indicated a superior or outstanding accomplishment by the instructor being evaluated. A value of 1 indicated a very poor performance. A rating of 0 indicated the observer was unable to evaluate the specific category.

A total of three classes were observed consisting of 18 trainees. Each class was observed for a period of two and one-half hours to obtain the assessment data.

The procedure for assessment consisted of one trained observer assigned from the Production Department Program Development Staff conducting the observation and recording the evaluation data. A written report was documented for each of the three classes observed. An assessment of performance for each class conducted during the experiment provided this researcher with data for determining a measure of actual performance as compared to a standard of acceptable performance. The instrument was designed internally to assess instructional methods within the Commonwealth Edison Company Production Training Department. See Appendix C for the Instructional Observation Report.

Descriptive Analysis of Internal Testing and Performance Gain

One of the questions pursued in this study was "Do the trainees learn from the program?" In order to determine the information from another source besides the foregoing research elements, this researcher compiled pre- and post-test data from four separate classes in three selected subject areas of the "B" Mechanics training program. The units of study selected are the three major areas of the training program for this work classification. See Appendix D for a copy of the test results.

The pre- and post-test scores for each group in the three major subject areas were analyzed using a t-Test for

Related Measures (Bruning and Kintz, 1977, pp. 12-15). The t-Test for Related Measures was used to determine the significance of a difference between two correlated means. The test is most commonly used when two scores are recorded for the same individuals.

The formula for the t-Test Analysis for Related Measures is as follows:

$$t = \frac{\bar{X} - \bar{Y}}{\sqrt{\frac{\sum D^2 - \frac{(\sum D)^2}{N}}{N(N-1)}}}$$

The procedural steps for determining the significant difference between two correlated means can be found in Appendix D. For purposes of this descriptive study, the researcher sought to verify trainee performance improvement resulting from a structural system of instructional design. There appears to be some disillusionment with experimentation in educational design using pre-post testing as an absolute measure of performance gain.

The pre-post test analysis follows an ex post facto design. The "ex post facto experiment" refers to efforts to simulate experimentation through a process of attempting to accomplish a pre - X equation by a process of matching on pre-0 attributes (Campbell and Stanley, 1963).

The experimental design in this research study addresses a case study that is widely used in educational research (Campbell and Stanley, 1963, p. 7). The experimental design deals with a number of uncontrollable variables that can jeopardize internal and external validity.

The first of these uncontrollable variables is "history." Many change-producing events can occur in addition to the experimenter's X. The span of time between pre- and post-testing may cause the difference in scores. The span of time in this case provides the instruction and content information in between the pre- and post-test period. The time lapse in this case becomes beneficial to the learner. Historical events are not commonplace in the environment being studied.

A second rival variable is "designated maturation." The term maturation is used to cover biological or psychological process which varies with the passing of time. The maturation of the trainees is insignificant in this case study. The variables of maturation in aging, hunger, fatigue, and boredom have little or no effect in the learning process. The effects of maturation would be the same even if no X had been introduced.

A third rival variable is the effect of testing. The intent of the pre-test was to determine the entry level of competence in the learner. The trainee taking the test for a second time provided a means of measuring the gain in performance as a result of guided instruction in the subject matter. The results indicated that a large gain was accomplished. The scores increased as a result of discovery in the problem-solving methods of instruction. The pre-test also had a secondary role of significance in revealing to the trainee a true competency level prior to receiving formal instruction. The reactive effect of pre-testing provides the instructor with a settling down of the "know it all" trainee. It provides a stimulus to the trainee to learn as a result of identifying the weaknesses of individual competencies.

A fourth rival variable deals with "instrumentation." The instrumentation or autonomous changes in the measuring instrument might account for 0_1-0_2 differences. These differences were not present in this study. The test items remained the same throughout the research activities. The measuring instrument was not changed during the time frame of this study.

A fifth variable considered was "statistical regression." Statistical regression was not evident in this study. No special treatment for the purpose of a remedial experiment was used; therefore, statistical regression was not an appropriate measure in this study. The participants in the study all received the same treatment during the instructional period and were not selected for independent reasons.

A sixth variable of participant selection did have an effect on trainee performance. The selection of participants was uncontrolled by this researcher. Each participant was selected by a manager at his assigned duty station. The selection of individuals to attend the formal training sessions is not based on previous experience or aptitude. The participants selected for training are for the most part randomly selected according to union seniority in job classification and job release availability. There is no standard of selection based on knowledge level or past experience. Therefore, a mixture of experienced and non-experienced trainees is assigned the same treatment in the training period. The results of performance within each group express the differences in experienced and non-experienced participants. A high score in the pre-test is a positive indicator of previous experience in the skills being tested.

A final variable is mortality or drop out of participants within each group. The mortality rate of group participants is very low. The participants are assigned training during working hours. They are paid their full salaries during the training period and the training assignment is an extension of their assigned duties. Each individual is requested to attend by the supervisor in charge of the work location. There is no penalty involved in refusal to attend classes or in discontinuing attendance on individual decisions. The trainee has an option to return to his work location at any time during the training period. Although this is an open option to each individual the mortality rate is almost non-existent. The mortality rate during this study remained at zero. This low rate is attributed to the attitude towards the training program and the opportunity to learn job-related skills while being paid to attend the training sessions.

In conclusion, the design and methods applied in this study are a descriptive analysis of instructional application and performance standards for improving technical skills in an industrial setting. Since the variables did not come to this researcher "ready made," the design for this study was somewhat creative and was a combination of practical application and statistical procedures.

The mission of the Commonwealth Edison Company Production Training Department is to develop through training, the knowledge, skills, and attitudes of personnel to help insure the safe, economical, and efficient operation of plant facilities and the work environment. The systems approach to training program design used in the Edison Company provides a means of accomplishing this mission.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

This study has been designed to maximize the likelihood of improving the method of content validation in technical skills education. Program planning and design decisions were analyzed as a means of assessing the congruency of task inventories and training program application. The statistical tests used were selected according to a standard practice of validating the data acquired for research documentation and application. The design is intended to improve technical skills performance using a collection of applicable techniques which are used in the electric utility industry. More specifically, the intended population for this study included Commonwealth Edison personnel assigned to the mechanical maintenance responsibilities at the Dresden and Zion Nuclear Power Plant facilities and the Shorewood Training Center in the State of Illinois.

The format of design follows a sequential order of applied techniques to provide direction to attain the objective of this study.

The findings of this study are separated into four major categories:

- Results of the Task Inventory
- Relationship Between Test Items and Objectives
- Results of Instructional Evaluation
- Internal Validity of Performance Gain

Each of the four categories provides an important segment of analysis within a system designed for practical application. The order of events in the study complements the orderly meshing of information to support each stage of development as it occurs.

In keeping with the prescriptions of professional training program design, the study is based on an analysis of the critical components in each category described. The success of the entire study hinged on the Task Inventory data; for without a comprehensive task analysis, the ensuing work would be incomplete and hence not valid.

Task Inventory Results

The task inventory data was gathered through the use of a 20-page questionnaire which required raters to rate each of the separate task statements of five separate dimensions. See Appendix A for a copy of the Task Inventory Questionnaire.

While the five dimensions described were measured on a scale of 1 (low) to 5 (high) for each separate task, raters were also asked to check those skills which felt were necessary for each of the 27 tasks listed in the questionnaire. A summary of the means for each of the ratings, as well as the percentage of agreements for each of the skills, can be found in Appendix A, Task Inventory Questionnaire for the Mechanical Maintenance "B"-Man's Position.

Percentages of Agreement in the Survey

The percentages of agreement among the survey participants provided strong support for the listing of job-related performance tasks in the data collection. The percentages of agreement resulted from totaling the frequencies for each item in the questionnaire.

Results of Data Collected

#1 Task

Piping to include threading, repair, and replacement

90%	1.	Knows how to select proper materials for strength and appropriate use
100%	2.	Knows how to use basic math skills such as addition, subtraction, and fractions
100%	3.	Knows how to use measuring tools such as rulers and scales

4. Knows how to use the following tools:

    100% a. basin, strap, and pipe wrenches
    96% b. reamers
    96% c. benders
    96% d. two and four jaw cutters
    100% e. hack saw
    86% f. power drill
    93% g. channel locks
    93% h. other tools such as hammers, pliers, and files

93% 5. Knows how to apply fasteners and adhesives

100% 6. Knows how to anchor and fasten materials

96% 7. Knows how to select the proper fittings

86% 8. Knows how to use proper follow-up procedures to flush and test for leaks

#2 Task

Packing valves and pumps

93% 1. Knows the different types of packing

90% 2. Has a working knowledge of valves and pumps

86% 3. Knows how to read equipment manuals

76% 4. Knows how to interpret the plant piece numbering system

96% 5. Knows how to select the proper tools

96% 6. Knows how to obey proper safety procedures for such things as isolation and draining

100% 7. Know how to follow proper Rad protection procedures

86% 8. Knows how to lubricate valves and pumps

83% 9. Knows how to functionally stroke equipment

#3 Task

Disassembling valves for inspection

100% 1. Has a working knowledge of rigging techniques

59% 2. Knows how to troubleshoot to determine the cause of problems

45% 3. Knows how to work with inaccessible valves

79% 4. Knows how to use special tools such as the torque wrench

93% 5. Knows how to use gasket materials

66% 6. Knows how to use insulation materials

96% 7. Knows how to obey standard safety procedures

#4 Task

Plugging condenser and heat exchanger tubes

83% 1. Knows how to use power tools such as torches, grinders, and impact tools

93% 2. Knows how to replace gaskets

96% 3. Has a working knowledge of rigging equipment

96% 4. Knows how to obey standard safety procedures

#5 Task

Rodding pipelines

96% 1. Knows how to use the power auger

86% 2. Knows how to disassemble and reassemble systems

96% 3. Knows how to follow out-of-service procedures

93% 4. Knows how to follow proper Rad protective procedures

93% 5. Knows how to cleanup and dispose of contaminated materials

#6 Task

Tightening fittings on hydraulic systems

93% 1. Has a working knowledge of hydraulic fittings

86% 2. Knows how to prepare materials for installation

93% 3. Knows how to use special tools such as flaring and swage equipment

90% 4. Knows the hazards of handling hydraulic fluids

#7 Task

Installing gaskets

96% 1. Knows how to select the proper materials

96% 2. Knows how to torque properly

93% 3. Knows how to use basic math skills such as addition, subtraction, and fractions

96% 4. Knows how to follow proper Rad protection procedures

90% 5. Knows how to lubricate gaskets

#8 Task

Changing vee belts on motors

93% 1. Knows how to use measuring tools such as tape and pulley gauge

96% 2. Knows how to use appropriate hand tools

93% 3. Knows how to make tension adjustments

#9 Task

Cleaning and changing filters

69% 1. Knows how to take equipment out-of-service

96% 2. Knows how to disassemble and reassemble filter equipment

100% 3. Knows how to use the proper hand tools

96% 4. Knows how to follow proper Rad protection procedures

#10 Task

Insulating

79% 1. Knows how to use measuring tools such as rulers and tape

76% 2. Knows how to select the proper tools

65% 3. Knows how to mix batch materials

79% 4. Knows how to follow proper cleanup procedures

#11 Task

Replacing pipe hangers

100% 1. Has a working knowledge of rigging techniques

69% 2. Knows how to interpret the instructions of Technical Staff Engineers

65% 3. Knows how to use insulation materials

100% 4. Knows how to obey standard safety procedures

#12 Task

Performing rigging operations

93% 1. Knows the basics of load factors such as ratings for slings

100% 2. Knows how to give and receive the proper hand signals

93% 3. Knows how to balance loads

100% 4. Knows how to use hoists to lift loads

90% 5. Knows how to tie knots to secure materials

90% 6. Knows how to block to avoid the movement of materials

86% 7. Knows how to crib to build support stands

100% 8. Knows how to wrap to avoid cutting materials

100% 9. Knows how to obey standard safety procedures

#13 Task

Building scaffolding

93% 1. Knows how to select proper scaffolding materials

90% 2. Knows how to use simple hand tools

93% 3. Knows how to assemble and disassemble scaffolding

90% 4. Knows how to frame and support a scaffold

100% 5. Knows how to obey the standard rules of safety

#14 Task

Grinding

96% 1. Knows how to operate the grinding machine

100% 2. Knows how to prepare a grinding wheel

100% 3. Knows how to change a grinding wheel

100% 4. Knows how to operate a hand-held grinder

#15 Task

Machining

96% 1. Knows how to set-up lathe and drill press operations

96% 2. Knows how to use basic machine tool accessories

96% 3. Knows how to use basic measuring tools such as micrometers and calipers

86% 4. Knows how to rig equipment when necessary

96% 5. Knows how to grind tool bits

100% 6. Knows how to obey standard safety procedures

#16 Task

Performing non-code welding

83% 1. Has a working knowledge of electrodes

93% 2. Knows how to prepare an area before welding

96% 3. Knows how to use the acetylene cutting torch

86% 4. Knows how to adjust the proper setting for pressure and amps

76% 5. Knows how to fabricate materials

96% 6. Knows how to use drills, grinders, and other power tools

93% 7. Knows how to use proper measuring tools

86% 8. Has a working knowledge of rigging techniques

96% 9. Knows how to wear protective equipment

96% 10. Knows how to use fire protection equipment

96% 11. Knows how to obey standard safety procedures

#17 Task

Operating the overhead crane

100% 1. Knows how to operate the controls on the crane

100% 2. Knows how to give and receive the proper hand signals

100% 3. Knows how to exercise patience during crane operations

93% 4. Has a working knowledge of load factors

100% 5. Has a working knowledge of rigging techniques

79% 6. Knows how to perform preventive maintenance on the crane

93% 7. Knows how to perform proper equipment inspection

100% 8. Knows how to obey standard safety procedures

100% 9. Knows how to operate the crane's safety escape device

#18 Task

Operating forklift truck

100% 1. Knows how to operate controls on the forklift in a coordinated manner

100% 2. Has a working knowledge of lift points

93% 3. Knows how to use the forklift in rigging operations

100% 4. Knows how to obey standard safety procedures

76% 5. Knows how to perform preventive maintenance on the forklift

#19 Task

Decontaminating equipment and materials

93% 1. Knows how to follow standard procedures for shielding, containing, transporting, and disposing waste materials

62% 2. Knows how to fabricate a waste container

72% 3. Knows how to use power and hand tools

#20 Task

Sandblasting

76% 1. Knows how to follow proper Rad protection procedures

96% 2. Knows how to set up equipment

79% 3. Knows how to select the correct abrasives

79% 4. Knows how to vacuum blast on flat surfaces

96% 5. Knows proper cleanup procedures for waste disposal

#21 Task

Steam cleaning

79% 1. Knows how to operate steam cleaning equipment

79% 2. Knows how to use proper cleaning agents

93% 3. Knows how to cleanup afterwards

93% 4. Knows how to obey standard safety procedures

#22 Task

Assembling crates and wooden boxes

96% 1. Knows how to use proper hand and power tools

96% 2. Knows how to layout materials

83% 3. Knows how to read blueprints

96% 4. Knows how to use proper measuring tools

86% 5. Has a working knowledge of rigging techniques

86% 6. Knows how to load materials into large containers

86% 7. Knows how to shield and insulate according to procedures

90% 8. Knows how to follow proper Rad protection procedures

93% 9. Knows how to obey standard safety procedures

#23 Task

Repairing auxiliary equipment (e.g. traveling screens)

93% 1. Has a working knowledge of rigging techniques

96% 2. Knows how to select and use proper tools

76% 3. Knows how to paint

83% 4. Knows how to weld

90% 5. Knows how to use fasteners

#24 Task

Performing routine building maintenance and repair work

86% 1. Knows how to perform plumbing on sinks and toilets

90% 2. Knows how to replace broken windows and perform glazing work

79% 3. Knows how to replace and repair tiling

96% 4. Knows how to hang poster boards and blackboards

90% 5. Knows how to operate snow plowing equipment

93% 6. Knows how to select proper cleaning agents

#25 Task

Painting

93% 1. Knows how to prepare an area before painting

90% 2. Knows how to use brush and roller

72% 3. Knows how to use spray equipment

#26 Task

Repairing door locks

96% 1. Knows how to use basic hand tools

86% 2. Knows how to disassemble and assemble lock mechanisms

100% 3. Knows how to read manufacturer's instructions

#27 Task

Operating vehicles at the station site

93% 1. Knows how to operate motor vehicles in accordance with the state's licensing rules

90% 2. Knows how to maintain motor vehicles

96% 3. Knows how to obey standard safety procedures

The consistency in percentage ratings above the average of 89.8% for all of the tasks listed shows congruency in the items listed and raters agreement.

The sample included 30 respondents of which only one was unable to complete the questionnaire form correctly. Hence all of the data reported in the Task Inventory is based on a sample of 29 respondents. The respondents either were in the "B"-man classifications or were considered subject matter experts on the position and its requirements. The latter group would include training personnel from the Shorewood Training Facility, while the former group was from two separate nuclear power stations, the Dresden Station and the Zion Station. The percentages of agreement by the subject matter experts (respondents) obtained from the questionnaires and interviews were valid measures of values, preferences, attitudes, and beliefs pertaining to the tasks listed in Table 1 (Tuckman, 1978).

Table 1 shows the means and standard deviations for each of the five dimensions rated for all 27 task statements. An examination of the size of the standard deviations reveals that the respondents were in fairly strong agreement with one another on most of the ratings. While this might appear to be a crude method for estimating reliability between raters, given the small and uneven size of the sample within each separate location, it did suffice as a method for examining inter-rater consistency.

Table 1

Summary Statistics
Means and Standard Deviations
For Each Task Dimension

	Frequency	Criticality	Difficulty	Safety	Composite Measure
Task #1 Piping to include threading, repair, and replacement	2.827	3.759	2.276	2.428	3.214*
	0.759	0.577	0.702	0.836	0.832**
Task #2 Packing valves and pumps	2.931	4.000	2.586	3.000	3.345
	0.923	0.845	0.682	1.000	0.669
Task #3 Disassembling valves for inspection	2.690	3.724	2.828	2.931	3.759
	0.890	0.922	0.889	1.099	0.689
Task #4 Plugging condenser and heat exchanger tubes	2.069	3.345	2.103	2.621	2.689
	0.651	0.936	0.772	1.147	1.004
Task #5 Rodding pipelines	2.241	3.069	1.828	2.414	2.483
	0.830	0.752	0.658	0.628	0.785
Task #6 Tightening fittings on hydraulic systems	2.414	3.483	2.276	2.931	3.034
	0.945	0.785	0.797	1.067	0.906
Task #7 Installing gaskets	3.689	4.069	2.172	2.552	3.379
	0.806	0.753	0.759	1.021	0.820
Task #8 Changing vee belts on motors	1.828	2.724	1.862	2.621	2.689
	0.848	0.922	0.743	1.049	1.072

* Mean of ratings for each dimension
** Standard deviation for each dimension

Table 1

	Frequency	Criticality	Difficulty	Safety	Composite Measure
Task #9 Cleaning and changing filters	2.828	3.414	2.069	2.483	2.724
	1.002	0.682	0.704	1.122	0.960
Task #10 Insulating	1.897	2.345	1.793	1.586	1.828
	1.113	1.111	1.082	1.210	1.255
Task #11 Replacing pipe hangers	2.207	3.448	2.414	3.138	3.138
	0.902	0.736	0.824	0.833	0.789
Task #12 Performing rigging operations	3.034	4.138	2.793	4.241	4.034
	0.865	0.875	0.902	0.786	0.778
Task #13 Building scaffolding	2.931	3.896	2.483	3.828	3.621
	0.884	0.859	0.738	0.848	0.903
Task #14 Grinding	3.172	3.414	2.362	3.862	3.517
	1.001	0.682	0.743	0.915	0.911
Task #15 Machining	2.552	3.931	3.310	3.690	4.310
	0.985	0.842	0.930	0.712	0.712
Task #16 Performing non-code welding	2.310	3.379	2.759	3.345	3.586
	1.039	1.083	1.154	1.078	1.118
Task #17 Operating the overhead crane	3.862	4.069	2.345	3.931	4.138
	0.990	1.099	1.111	1.099	1.125
Task #18 Operating fork-lift truck	3.241	3.517	2.207	3.586	3.586
	0.951	0.829	0.940	0.780	0.733
Task #19 Decontaminating equipment and materials	2.793	3.310	1.655	2.621	2.828
	1.319	1.198	1.078	1.425	1.136

Table 1

	Frequency	Criticality	Difficulty	Safety	Composite Measure
Task #20 Sandblasting	2.724 0.841	3.138 0.953	1.862 0.743	2.896 0.900	2.793 0.978
Task #21 Steam cleaning	1.965 1.085	2.379 1.049	1.896 0.976	2.862 1.156	2.586 1.053
Task #22 Assembling crates and wooden boxes	2.517 0.949	2.896 0.939	2.138 0.875	2.207 0.774	2.724 0.960
Task #23 Repairing auxiliary equipment (e.g., fish baskets, wire cages, traveling screen baskets)	2.345 0.769	3.069 0.961	2.414 0.867	2.793 0.902	2.931 0.884
Task #24 Performing routine building maintenance and repair work	3.034 1.052	3.138 0.990	2.276 0.922	2.689 0.849	2.931 0.884
Task #25 Painting	2.345 1.142	2.310 1.039	1.552 0.948	1.793 0.818	2.241 0.872
Task #26 Repairing door locks	2.241 0.912	2.966 0.865	2.621 0.903	1.966 0.865	2.966 0.865
Task #27 Operating vehicles at the station site	3.379 0.862	3.448 0.827	2.069 1.033	2.896 0.860	3.276 0.922

The reliability of the data listed in Table 1 was based on the process of examining individual tasks to determine the performance elements, skills, knowledges, and job conditions required for job competency. The data base information was collected by using 29 subject matter experts located at three work locations. The subject matter experts were interviewed by a team of trained staff members assigned from the Shorewood Training Center. The data collected in the interviews and survey forms was analyzed for agreement between the participants of the survey. See Percentages of Agreement recorded on pages 52-62.

Table 2 describes the comparative task ratings for each of the five dimensions according to mean values recorded in Table 1. The significance for showing the comparative task ratings is to identify the reason for the high or low rank appearance of each task listed. Each task was assigned a rank position according to the numerical values recorded by the raters. Using the means listed in Table 1, it was then possible to rank each task against one another on a scale of 1 (high) to 27 (low) for each of the five dimensions.

Table 2

Comparative Task Ratings for Each of the Five Dimensions*

	Frequency	Criticality	Difficulty	Safety	Composite Measure
Task #1 Piping to include threading, repair, and replacement	11	7	12	22	12
Task #2 Packing valves and pumps	8	4	6	9	10
Task #3 Disassembling valves for inspection	14	8	2	10	4
Task #4 Plugging condenser and heat exchanger tubes	24	16	17	17	21
Task #5 Rodding pipelines	21	20	24	23	25
Task #6 Tightening fittings on hydraulic systems	17	10	12	10	14
Task #7 Installing gaskets	2	2	16	20	9
Task #8 Changing vee belts on motors	27	24	22	17	21
Task #9 Cleaning and changing filters	10	13	19	21	20
Task #10 Insulating	26	26	25	27	27

* Mean values for each of the dimensions listed in Table 1 were used to rank each of the 27 tasks.

Table 2

	Frequency	Criticality	Difficulty	Safety	Composite Measure
Task #11 Replacing pipe hangers	23	11	8	8	13
Task #12 Performing rigging operations	6	1	3	1	3
Task #13 Building scaffolding	8	6	7	4	5
Task #14 Grinding	5	13	10	3	8
Task #15 Machining	15	5	1	5	1
Task #16 Performing non-code welding	20	15	4	7	6
Task #17 Operating the overhead crane	1	2	11	2	2
Task #18 Operating fork-lift truck	4	9	15	6	6
Task #19 Decontaminating equipment and materials	12	17	26	17	18
Task #20 Sandblasting	13	18	22	12	19
Task #21 Steam cleaning	25	25	21	14	24
Task #22 Assembling crates and wooden boxes	16	23	18	24	20

Table 2

	Frequency	Criticality	Difficulty	Safety	Composite Measure
Task #23 Repairing auxiliary equipment (e.g., fish baskets, wire cages, traveling screen baskets)	18	20	8	15	16
Task #24 Performing routine building maintenance and repair work	6	18	12	16	16
Task #25 Painting	18	27	27	26	26
Task #26 Repairing door locks	21	22	5	25	15
Task #27 Operating vehicles at the station site	3	11	19	12	11

Table 3 shows an intercorrelation matrix for the five separate dimensions described earlier (pp. 38, 39). Because the correlations were based on the rankings shown in Table 2, Spearman's rank order correlation was computed for each of the comparisons. The following formula describes the computational procedures used (Bruning and Kintz, 1977, pp. 175-178). $rho = 1 - \frac{6\sum D^2}{N(N^2 - 1)}$

This statistic is particularly appropriate when it is necessary to determine the relationship of this type of data.

The low correlation between frequency and criticality shown in Table 3 emphasizes the interesting notion that many times tasks are performed infrequently but they are rated very high in importance. It should also be noted in the data collection that criticality, difficulty, and safety all seem to correlate very closely with one another. This is not surprising since tasks requiring an element of safety are often hard to do and very critical to successful job performance, regardless of frequency performed. Finally, the fact that all four rating categories correlate highly with the composite measure speaks well for the internal consistency of the questionnaire.

Table 3

Intercorrelation Matrix for the Five Ratings Categories in the Task Analysis Questionnaire*

	Frequency	Criticality	Difficulty	Safety	Composite Measure
Frequency	1.00	.70	.24	.47	.63
Criticality	.70	1.00	.62	.67	.86
Difficulty	.24	.62	1.00	.62	.81
Safety	.47	.67	.62	1.00	.80
Composite Measure	.63	.86	.81	.80	1.00

* Data taken from the results of the Task Analysis Questionnaire shown in Appendix A using 27 task statements which were rated by 29 subject matter experts.

The rank order of tasks shown in Table 4 was derived from Table 2 and the form used in Appendix A. The five factors of frequency, criticality, difficulty, safety, and composite measure provided the numerical values to rank order each of the tasks listed. Each task was rated according to an averaging of the five dimension numerical values assigned by the raters. The lower the numerical value recorded in the ratings the higher the task appears in the rank order. The analysis provided a ranking according to how crucial the task is to improved safety and overall job performance.

To further reduce the data into meaningful form, all five rankings were added together and averaged to obtain an overall task average. This then permitted a final ranking to be done which allows a judgment to be made about relative task importance. For example, a look at the first six tasks shows that working around heights or with suspended objects means safety is involved and is therefore key to the "B"-man's job performance. Maintenance of valves is also critical, and this is not surprising given the importance of preventing leaks of radioactive water in a nuclear station.

Performing rigging operations, for example, involves a high risk in safety and possible equipment damage. Performing rigging operations and operating overhead cranes are associated skills. The proper rigging of equipment prior to a crane lift involves both mental and manipulative skills. Selecting the correct rigging tools and following approved procedures requires calculative and interpretative skills and adherence to established practices. The lift operation requires interpretative and manipulative skills. The tasks are separated by a difference in levels of performance, but are very dependent on each other according to the dimensional factors involved in the analysis.

Finally, machining is rated highly and this is natural since the position is in the area of mechanical maintenance. Actual machining requires high manipulative and mental skills. To follow a blueprint and create an object according to specific dimensions requires interpretative and manipulative skills. Machining shows a high frequency rating and a median range rating in safety and criticality. It must be pointed out that the tasks performed in a machining operation can change according to conditions. For example, a high-radiation area would increase risk to personnel. The machining could be a simple grinding operation requiring little technical skill, but the safety risk factor would be high. Conditions of performance can change the factor ratings accordingly. For the purposes of this study, the norm of operational conditions was the only factor considered. Abnormal conditions are unpredictable and beyond the scope of this research activity.

A further look at Table 4 reveals that the last 13 tasks can be classified for the most part as more menial than the preceding 14. In some ways these tasks, such as routine building maintenance, painting, and repairing door locks, can be seen as requiring lesser skills. Other tasks in this group reflect the need to perform radiation protection such as decontaminating equipment, steam cleaning, and assembling crates and wooden boxes for the shipment of radioactive material.

Table 4

Tasks in Order of Rank*

Rank Order		Overall Task Average
1)	Performing rigging operation	2.8
2)	Operating the overhead crane	3.6
3)	Machining	5.4
4)	Building scaffolding	6.0
5)	Packing valves and pumps	7.4
6)	Disassembling valves for inspection	7.6
7)	Grinding	7.8
8)	Operating forklift truck	8.0
9)	Installing gaskets	9.8
10)	Performing non-code welding	10.4

* Rankings were derived by averaging the five rankings in Table 2. The lower the average rank, the more crucial the task to job performance.

Table 4

Rank Order		Overall Task Average
11)	Operating vehicles at the station site	11.2
12)	Tightening fittings on hydraulic systems	12.6
13)	Replacing pipe hangers	12.6
14)	Piping to include threading, repair, and replacement	12.8
15)	Performing routine building maintenance and repair work	13.6
16)	Repairing auxiliary equipment	15.4
17)	Cleaning and changing filters	16.6
18)	Sandblasting	16.8
19)	Repairing door locks	17.6
20)	Decontaminating equipment and materials	18.0
21)	Plugging condenser and heat exchanger tubes	19.0
22)	Assembling crates and wooden boxes	20.2
23)	Steam cleaning	21.8
24)	Changing vee belts on motors	22.2
25)	Rodding pipelines	22.6
26)	Painting	24.8
27)	Insulating	26.2

The training program has been developed in accordance with this task ranking. Strong emphasis has been placed on rigging, machining, and valve maintenance.

Meanwhile, routine maintenance of buildings and grounds is not stressed as heavily, except where there is a need to protect against the possible effects of radiation.

Tentative Conclusions/Hypotheses

- The instrument provided a related sampling of task items for the respondents to make judgments and rate each critical item separately.
- The task inventory provided a means to show an intercorrelation of job task items and experienced worker inputs.
- The respondents were in fairly strong agreement with one another on most of the ratings. The results of the questionnaire showed a positive response to the items listed. This response indicated there was little or no difference in perceived job relatedness and the actual training program provided.

It should be noted that in some cases the inventory list will be somewhat different from the original training program or job specification; some areas will have been rejected and others added. This usually occurs if the original specification is out of date, but sometimes the list is just badly written in the first place. The extent to which one's list varies from the original will also depend on how well the instrument for analysis is designed.

The most common failing in existing training programs is that they tend to be vague, since they are usually written in non-behavioral terms. Thus the most important step at this stage is to write the specification in behavioral or "doing" terms so that the behavioral components of the skills and knowledge to be tested are clearly stated.

Results of Test Items and Objectives Comparison

Although the course objectives and test items had been previously determined, this research sought to establish a congruence for each test item with pre-established objectives. Initially, each test item was matched to an objective stated within the three subject areas selected for this study. See Appendix B.

The instructional staff at Shorewood and representatives of the maintenance staffs at each nuclear plant involved in the study unanimously selected three specific training modules which were related to the particular job classification being studied. The subject areas selected are major categories within the job task inventory listing and were determined to be essential to job performance in the "B" mechanic classification. At the behavioral specification stage, the terms of what the trainee is actually expected to do were essential. The behavioral specification was used as a reference document for actual test production and detailing for content analysis.

Tentative Conclusions/Hypotheses

- Eighty-two percent of the test items matched the objectives. The test items that did not correlate to an objective were covered in the training module information and instruction.
- The behavioral specifications could have been stated more clearly according to Mager's criteria for preparing instructional objectives. An example of an acceptable behavioral objective is, "To be able to solve quadratic equations" (Mager, 1962, p. 14). An example of a poorly written behavioral objective is, "The trainee will be familiar with valve bonnet designs." (See Appendix B, Objective 2.) The term familiar is open to too many interpretations and not explicit enough to describe what the learner is expected to do. A better statement would be, "The trainee will be able to identify the difference in valve bonnet designs." In addition to the improvement of stated behavioral specifications, the test items could be improved accordingly.
- For purposes of the research study the matching of the test items to the objectives emphasizes the need for congruence between test items and objectives.

It is recommended that the training module objectives and test items be reviewed for possible improvement and standardized test design. The emphasis of clarity in stating both the desired behavior and test items cannot be over-emphasized. See Appendix B.

Results of Instructional Evaluation

The measurement of instructor performance against stated training objectives and instructor qualifications was conducted by members of the Production Training Staff. The selected observers were trained in the use of the evaluation instrument and its application specifically for this study. The measures of the performances were recorded in the following categories: demonstration of technical competency in the subject area being taught, use of communication skills, maintenance of trainee interest and discipline, accomplishment of training objectives, effective use of training materials and devices, and maintenance of presentation pace and schedule.

The instructor performance evaluations were conducted by direct observation and instructor conference. The measurement instrument provided an accounting of instructor performance in each class identified in the study. See Appendix C.

Table 5 shows the averages of the instructor evaluation ratings using six levels of performance. The consistency of the high ranking of performance is attributed to instructor training programs at Edison, which address all of the competencies shown in Appendix C. The two instructors observed have demonstrated competencies in the subject matter and instructional methods. Each of the subjects observed have an average of twenty years of on-the-job experience and have completed all instructor certification requirements at the Technical Trainers Institute, University of Wisconsin, Eau Claire, Wisconsin.

Table 5

Summary of Evaluation Reports*

Planning and Preparation	4.27
Organization of Trainees and Classroom	4.93
Instruction and Interaction	4.24
Assessment	4.11
Competencies and Professional Development	4.38
Human Relationships	4.19

* Mean average of three instructors evaluated by three separate observers. The value of 5.0 is superior rating compared to a low value of 1.0 rating indicating very poor.

In further study of the available data, this researcher placed the observer ratings into four categories (very high, high, low, very low) to show the frequency distribution of the three observers. In order to assess the potential reliability of the ratings, the evaluators were asked to observe specific items listed within six major categories. The rating scale of 0-5 was converted into the above four categories to report the distribution of observer ratings in a combined total for each major category. The ratings for each category were counted for a total of how many times each rater indicated the same numerical value for the categories listed. The totals for each category are varied according to the number of items in each major heading of the instrument. According to the data recorded from the evaluation report all of the ratings were distributed in the (very high) or (high) category of instructor performance.

Table 6 shows the results of the frequency distribution analysis. See Appendix C for the instrument used to collect this data.

Table 6

Frequency Distribution of Observer Ratings*

Evaluation Category	Observer Ratings Very High	 High	 Low	 Very Low
Planning and Preparation	5	13	0	0
Organization of Trainees and Classroom	18	0	0	0
Instructor and Interaction	34	21	0	0
Assessment	2	16	0	0
Competencies and Professional Development	15	27	0	0
Human Relationships	3	12	0	0

* The numerical values in Table 6 indicate the frequency totals for each category listed in the evaluation instrument shown in Appendix C. The total combined responses of the three observers are summarized for each category rated by the observers.

The inter-rater reliability of the data for determining instructor performance was calculated using the evaluation reports of each observer on instructor performance. Table 7 shows the findings of the inter-rater reliabilities. Raters 2 and 3 evaluated the same individual, even though it was on separate occasions. Hence, the reliability is higher between them than in their separate agreement with rater 1 who looked at an entirely different instructor. While the agreement between raters 2 and 3 is not exceptionally high, it is statistically significant at the .01 level and does show that both raters were thinking pretty much along the same lines when they gave the evaluations.

Table 7

Inter-rater Reliability Coefficients for Instructor Performance*

	Rater 1	Rater 2	Rater 3
Rater 1	---	0.316	0.350
Rater 2		---	0.685
Rater 3			---

* Data taken from the results of the Instructional Observation Report shown in Appendix C using 6 areas of teaching competence which were rated by 3 program development specialists at CECO's Shorewood Training Facility.

Internal Validity of Performance Gain

The test items are intended as a formative evaluation of internal process to obtain data for instructors to use to increase efficiency and effectiveness of their instructional materials. The emphasis in this formative evaluation is on the collection of data in order to revise the instructional materials and test items in a small group evaluation of program design and instruction. The target population selected for this phase of the study provided a field evaluation of specific groups with a total N of 27 participants.

The field evaluation instrument used in this study provided a data base for determining the significance of difference between two correlated means. The test data collected for pre- and post-training were used as an evaluation of performance gain for each participant. The verification of performance gain was calculated using the t-Test for Related Measures (Bruning and Kintz, 1977, pp. 12-15). Table 8 summarizes the t-Test results.

Table 8

t-Test for Related Measures for Pre- and Post-Test Scores of Four Treatment Groups Enrolled in Unit IV of Mechanical Maintenance Training*

	Subject Category	N	df	Pre-Test	Post-Test	t	P
Group I	Pumps	7	6	48.1	90.4	14.94	<.001
	Valves	7	6	58.1	87.5	8.82	<.001
	Piping	7	6	25.6	89.4	24.24	<.001
Group II	Pumps	5	4	41.4	81.8	7.03	<.001
	Valves	5	4	56.0	91.0	22.15	<.001
	Piping	5	4	49.0	86.8	9.67	<.001
Group III	Pumps	7	6	55.6	91.4	9.31	<.001
	Valves	7	6	55.0	94.3	7.92	<.001
	Piping	7	6	57.4	90.7	7.67	<.001
Group IV	Pumps	8	7	47.3	93.9	5.83	<.001
	Valves	8	7	22.5	87.5	15.40	<.001
	Piping	8	7	56.3	84.4	5.19	<.001

* Table 8 represents the results of testing the four groups enrolled in Unit IV Mechanical Maintenance classes.

The determination of t-value significance was dependent on the degrees of freedom (df) and the test scores recorded. See Appendix D for detailed analysis of the pre- and post-test scores of the four groups studied.

Table 8 reveals that all groups tested had a t-value significant at the $<.001$ level. As a result, the test score differences between pre- and post-training supports the hypotheses of this study. The measurement of performance gain between entry level and the conclusion of the training sessions is significant in determining the accomplishment of pre-stated objectives of instructional intent. The trainees are selected on a seniority or availability basis. The experience level of each participant is not known prior to attending the classes. The experience level of the trainee varies between no previous experience to Nuclear Navy trained veterans of six years intensive training both formal and informal. It is suggested that an aptitude screening of participants prior to assignment to training would possibly produce a different correlation of performance gain between entry level and post-training evaluation. See Appendix D for t-Test data.

Tentative Conclusions/Hypotheses

- The instrument provided a survey of performance gain.
- The t-Test for Related Measures documented the level of significance using a sample statistical measurement of performance gain.
- The level of significance for each group was well beyond the $<.001$ level.
- The intent of measuring performance gain to show accomplishment was achieved.

The validity of performance gain as related in this research is totally dependent on mastery based on the task inventory and behavioral objectives as specified earlier in the study. The reliability of each test item is not the intent of this research activity. A follow up study of in-plant application of performance skills and the retention of learned skills after a specified duration would provide a separate research activity beyond the scope of this study.

CHAPTER V

FINAL SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of the Study

Using a systems approach to content validation, this study sought to provide a model for others to follow in designing training program content and measuring performance results. One of the nuclear electric power industry's major goals is to enhance plant safety and reliability through the promotion of high quality personnel training and education programs. This can be accomplished by developing training program specifications, evaluating results of performance against these specifications, and documenting this evidence with statistical data. The study provides the specifications in four separate categories in sequential order.

The initial phase of study involved both supervisory and job incumbents to identify the task elements and formulate a rating system for the data collection and ranking of the task elements. The rating of identified task elements involved a sample of 29 experienced maintenance personnel working in the Commonwealth Edison nuclear power plants and training facility. The raters were selected from the Dresden Nuclear Power Plant, Morris, Illinois; Zion Nuclear

Power Plant, Zion, Illinois; and the Shorewood Technical Training Facility, Shorewood, Illinois. Although the initial sample included 30 participants, one case was deleted because of experimental mortality.

All 29 participants were administered a Task Inventory Questionnaire developed by this researcher. The survey questionnaire provided the establishment of congruency between the rank order of task inventory items and the instructional training program. Each task inventory item was rated according to five separate task dimensions and rating factors: frequency, criticality, difficulty, safety, and composite measure. Each of the five factors was analyzed to determine the order of each task listed. The ranking provided an indicator of which tasks were the most critical within the specific job classification. The most critical items identified according to rank become "musts" to appear in the instructional content.

Findings

The percentage of agreement between the survey participants provided congruence between the job related tasks in the specific job classification being studied. The results of the final statistical analysis in this phase using the intercorrelation matrix for the five separate dimensions and Spearman's rank order correlation or rho were as follows: The rank order of task items according to importance is dependent on safety and a high order of mental/manipulative skills. It appears that the raters were consistent in their beliefs that safety is an important item, but mental and manipulative skills are aligned with safety practices.

The results obtained in the Task Inventory would seem to indicate a statistically significant agreement of congruence between the participants of this study and the training program content. The rank order listing was in full agreement with the specific subjects being taught at the training center site.

Congruence Between Test Items and Objectives

The congruence between test items and training module objectives was analyzed by means of a survey of each test item and matching it to a specific behavioral objective stated within each training module content.

Findings

The results obtained from the analysis were logically significant for determining if the performance test items were related to the behavioral specifications. The behavioral specifications were used as reference documents to establish a congruence of performance testing and desired outcomes resulting from the specific objectives stated.

The ratio of 5:1 was obtained in the analysis of test items and objectives. There were few test items that did not show congruence to stated objectives. The test items that were not matched were covered in the instruction and training module content. The three training modules selected for the analysis were representative of three major categories in the job classification being studied. The analysis of three separate training modules showed no significant departure from acceptable systems program design (Mager, 1973). Although the results obtained were acceptable, it is recommended by this researcher that more importance could be placed on test design and clarity for a more accurate correlation between objectives and test items.

Instructional Evaluation

The instructional evaluation provided a determination of competency level in instructional skills. The technique of direct observation by trained evaluators within the Commonwealth Edison Production Training staff provided the measures of performance based on a documented accounting of instructor performance in three separate instructional groups. The observers rated each of the instructors on 61 separate items within six major categories.

Findings

The mean averages of the three instructors observed confirmed the high competency level of instruction. These findings were summarized using a frequency distribution of observer ratings prepared by this researcher. The results indicated that all of the instructors observed were rated in the very high and high ranges of competency levels. The observer ratings were recorded in a summary of the rating values using mean averages for each category observed. The following ratings were reported: Planning and Preparation (4.27), Organization (4.93), Instruction and Interaction (4.24), Assessment (4.11), Competencies and Professional Development (4.38), and Human Relationships (4.19). The overall average of all categories results in a value of 4.35 out of a possible superior rating of 5.0. The descriptive analysis indicates that the professional training of the instructors is evident according to the competency levels reported.

In addition to the instructor evaluations, trainee activities were also observed. The results of the trainee activities measures indicated that there was little or no negative response to the training activities by the learners. The lack of negative responses is assumed to be associated with the affective domain of interest, attitude, and values. The classroom and lab activities are structured to capture the interest of the learner and provide a learning experience commensurate with his job responsibilities.

Internal Validity of Performance Gain

The internal validity of performance gain resulted in a descriptive evaluation of the instructional process and program design. The emphasis of the evaluation is to provide feedback information for analysis. The field evaluation consisted of four separate groups with a total N of 27 participants. The data collected consisted of pre- and post-test scores to determine entry behavior and post behavior resulting from the instruction. Each participant was evaluated individually to verify performance gain resulting from the instruction. The verification of performance gain was calculated using a t-Test for Related Measures (Bruning and Kintz, 1977).

Findings

The field evaluation instrument provided a data base for determining the significant difference between two correlated means. The t-Test results indicated that all four of the treatment groups studied achieved significant gain resulting from the instruction. A comparison of three subject areas within the four groups studied resulted in a t-value level of significance below the .001 using the t-Test for Related Measures (Bruning and Kintz, 1977) formula. Aptitude screening of the participants in this study was not evident prior to the assignment of training activities. It is assumed that the difference between entry behavior and post behavior is possibly attributable to experience. Although the ex post facto design of this study does not include a thorough study of manipulative variables the conclusion of results was based on a simplified analysis of behavior change resulting from the controlled variables. The logic of inquiry resulted in a documentation that a performance gain was accomplished by the participants considering entry level competency as compared to post training competency. This supports the hypotheses of this study:

H_1: All trainees who have certain basic aptitudes can be taught to perform a particular industrial training skill.

H_2: Training which requires individuals to show mastery of prerequisite skills before attempting mastery of job-related skills will be more effective than traditional industrial training which does not rely on sequential learning.

The sequential task oriented systems approach to training program design provides a methodology to accomplish performance gain. Traditionally, the design of training programs in the electric utility industry has not relied on a professional approach to developing learning systems. The desired results may be the same but the actual results may differ.

Conclusions

This study was designed to formulate a system for collecting, analyzing, and interpreting human performance data as related to technical skills education. A specific job position within the electric utility technical skills area was analyzed as a means for providing a case study to describe the parameters of designing a system for measuring instructional intent. The separation of major phases in the study provided a means of applying statistical analysis and documentation of performance standards relative to the participants. The basic premise underlying this research assumed that all trainees who have certain basic aptitudes can be taught to perform at an acceptable level of competency if the instructional design follows a sequential order of tasks identified within the job classification and assigned work activities.

The following conclusions were reached from the findings of this investigation and apply specifically to an industrial application of job performance in the electric utility industry:

- Instructional programs that are designed according to job analysis and an identification of needs are more likely to succeed. The analysis of a task inventory to determine priorities within the scope of the job responsibilities provides an exact relationship between the instructional program and desired performance outcomes.

- The congruence of objectives and the evaluation instrument is essential to establish documented evidence that the learner met the stated behavioral objectives and to establish a competency level of acceptable performance.
- Instructor competency and student interaction contribute to an effective learning experience. The instructor competencies in instructional methodology and subject matter expertise are essential. The participants enter the instructional programs at all levels of previous experience. Participant learner experience has an effect on instructor/learner interaction. The screening of competency levels of the participants would alleviate the differences of competency levels among the participants.
- The internal validity of performance gain influences the program design. Pre- and post-testing provide information relative to entry level skills and post level skills. The analysis of performance before and after the instructional period provides a measure of performance gain resulting from the learning experience. The performance gain can be attributed

to the instructional competencies, the instructional content, or both. The research supports both influences as essential to effective instructional programs.

Recommendations

Because the systems approach to industrial training program design represents such an important area in the electric utility industry, particularly to the nuclear technology application, and as a result of this descriptive study the following recommendations are made:

- Technical skills programs within the electric utility industry need to place more emphasis on formalized training program technology as well as the relationships of job responsibility and the skills required to function competently within the scopes of assigned work activities.
- Technical skills programs need to provide a learning experience associated with the instructional intent. The desirable outcomes must result from program design, instructional competency, and participant interaction within the training environment. The competencies of training staff members are synonymous with training program effect. Professional academic experience blended with associated work experiences provides the training staff members the skills of

program design, instructional methodology, evaluative skills, and administrative expertise. Since it appears that the training staffs of most major utility organizations are responsible for a capital investment of millions of dollars in developing human factor competencies, exposure to a professional training experience in the skills of curriculum development and administration seems desirable.

- The establishment of performance standards provides a guideline to follow for both the participant learner and the evaluator. The measure of performance becomes less arbitrary and subjective in determining acceptable performance levels in technical skills education.
- A company's training program for any job classification should incorporate more than just the testing program that is typically the focus of validation studies. It should also include a front-end analysis of tasks to be performed, experience levels of the participants, and realistic performance standards associated with the job.
- Program content validation resulting from a concurrent descriptive study limited this research activity to present employees. Since this group was not selected according to experience levels, the pattern of test criterion correlations was distorted. The

screening of participants according to experience levels may prove to be a factor affecting the economics of who should attend the training sessions to improve job performance.

The foregoing discussion should not be construed to mean that the results obtained in this study are worthless. The homogeneous grouping of the participants according to experience levels and test performance in the skills of the job prior to enrollment provides an alternative to present day practices in our industry. The indication of experience level would provide another factor for investigation and possible change in the selection of the participants who would be scheduled for training.

Suggestion for Further Research

- The validation of performance gain could be improved with a focus on the verification of the reliability of test items. The experimental control of the participants and a redesign of the testing format prior to further research would provide a more comprehensive statistical study for determining reliability.
- This study was limited to one work classification within the three Commonwealth Edison Production Department locations. This study could be replicated throughout the technical skills industry as a model

for validating training program content and performance standards application.

- Further study is needed as a follow-up to determine how well the participants perform at the job location in actual performance of assigned work activities. In addition to a checkup on competence levels achieved at the work site, the measure of skills retention would have an impact on how often retraining would be needed.

A Final Word

Since the nuclear power incident in Harrisburg, Pennsylvania on March 28, 1979, one of the major goals of the nuclear electric utility industry is to enhance plant safety and reliability through the promotion of high quality personnel training and education programs.

Numerous factors influence the decisions of training program design. These influences include how well the instructional specifications are identified in systematic analysis of the tasks involved in performing each job at the nuclear power plant which is important to safe, reliable operation.

In the contemporary setting of training, the complexity of interacting variables must be accepted. It is this phenomenon which the systems approach can best accommodate. The systems approach appears to make it possible to identify functions and components, describe their interaction, and then predict, observe, and measure the effect of change and variations in components and functions. The sequence of steps in a decision-making structure outlines a sequence for exploring training innovation.

The need for continuing research in validation and performance testing is more important than ever since the accident report at the Three Mile Island Nuclear Station. Incompetencies and human error are intolerable in the high technology of nuclear application to energy producing industries.

Finally, the training responsibility is becoming increasingly complex in terms of technology, program development, evaluation, and documentation of performance gain. The problems associated with learning systems are generic to most industries. This supports the need for further research activities in technical skills education.

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APPENDIX A

TASK INVENTORY QUESTIONNAIRE FOR THE MECHANICAL MAINTENANCE "B"-MAN'S POSITION

NAME: ______________________________

STATION LOCATION: ______________________

INSTRUMENT FOR SURVEY

Instructions: This form contains a listing of tasks which are said to be part of the B-Man's position. Please review each task and then do the following things: (1) rate each task according to the dimensions listed below and (2) review, and if necessary, modify the listing of knowledges and skills which are needed to perform each task.

On the next page you will be asked to rate each task which is listed on the left-hand side of the page on the following dimensions: (1) frequency, (2) criticality or importance, (3) difficulty, (4) risk or safety hazard, and (5) attention to detail. All of these dimensions are evaluated on a five-point scale and are explained in more detail below:

Frequency (F): the extent to which a task is done or the amount of the B-Man's time spent working on the task

5 = A great deal (approximately 20% of your time or more)
4 = More than average
3 = An average amount (approximately 10% of your time)
2 = Some, but less than average
1 = None, a very small amount, or does not apply

Criticality (C): the degree of importance of the task to the overall functioning of the power station

5 = Extremely important to your job
4 = Important to your job
3 = About medium importance to your job
2 = Unimportant to your job
1 = Extremely unimportant to your job

Difficulty (D): the amount of knowledge or level of skill required to perform the task in an acceptable manner

5 = Extremely difficult to learn and perform
4 = Rather difficult to learn and perform
3 = About average in difficulty level
2 = Relatively easy to learn and perform
1 = Exceptionally easy to learn and perform

Safety (S): the degree to which performing the task creates a safety hazard or risk of danger for people and/or property

5 = Extremely high risk of personnel injury and/or property damage
4 = About average in risk
3 = Some degree of risk involved
2 = Rather low risk to people and/or property
1 = Almost no hazard involved

Composite Measure (CM): the amount of attention to detail which is needed to perform the task when taking into consideration frequency, criticality, difficulty, and safety

5 = Demands enormous attention to detail
4 = Demands considerable attention to detail
3 = Requires moderate attention to detail
2 = Requires some attention to detail
1 = Requires almost no attention to detail

TASK	F	C	D	S	CM
Piping to include threading, repair, and replacement	_____	_____	_____	_____	_____

Knowledges and Skills for Piping (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to select proper materials for strength and appropriate use

_____ 2. Knows how to use basic math skills such as addition, subtraction, and fractions

_____ 3. Knows how to use measuring tools such as rulers and scales

4. Knows how to use the following tools:
    - _____ a. basin, strap, and pipe wrenches
    - _____ b. reamers
    - _____ c. benders
    - _____ d. two and four jaw cutters
    - _____ e. hack saw
    - _____ f. power drill
    - _____ g. channel locks
    - _____ h. other tools such as hammers, pliers, and files

_____ 5. Knows how to apply fasteners and adhesives

_____ 6. Knows how to anchor and fasten materials

_____ 7. Knows how to select the proper fittings

_____ 8. Knows how to use proper follow-up procedures to flush and test for leaks

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

TASK	F	C	D	S	CM
Packing valves and pumps	_____	_____	_____	_____	_____

Knowledges and Skills for Packing (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows the different types of packing

_____ 2. Has a working knowledge of valves and pumps

_____ 3. Knows how to read equipment manuals

_____ 4. Knows how to interpret the plant piece numbering system

_____ 5. Knows how to select the proper tools

_____ 6. Knows how to obey proper safety procedures for such things as isolation and draining

_____ 7. Knows how to follow proper Rad protection procedures

_____ 8. Knows how to lubricate valves and pumps

_____ 9. Knows how to functionally check equipment

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

TASK	F	C	D	S	CM
Disassembling valves for inspection	_____	_____	_____	_____	_____

Knowledges and Skills for Disassembling (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Has a working knowledge of rigging techniques

_____ 2. Knows how to troubleshoot to determine the cause of problems

_____ 3. Knows how to work with inaccessible valves

_____ 4. Knows how to use special tools such as the torque wrench

_____ 5. Knows how to use gasket materials

_____ 6. Knows how to use insulation materials

_____ 7. Knows how to obey standard safety procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

TASK	F	C	D	S	CM
Plugging condenser and heat exchanger tubes	_____	_____	_____	_____	_____

Knowledges and Skills for Plugging (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to use power tools such as torches, grinders, and impact tools

_____ 2. Knows how to replace gaskets

_____ 3. Has a working knowledge of rigging equipment

_____ 4. Knows how to obey standard safety procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

<u>TASK</u>	F	C	D	S	CM
Rodding Pipelines	_____	_____	_____	_____	_____

Knowledges and Skills for Rodding (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to use the power auger

_____ 2. Knows how to disassemble and reassemble systems

_____ 3. Knows how to follow out-of-service procedures

_____ 4. Knows how to follow proper Rad protection procedures

_____ 5. Knows how to clean-up and dispose of contaminated materials

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

<u>TASK</u>	F	C	D	S	CM
Tightening fittings on hydraulic systems	_____	_____	_____	_____	_____

Knowledges and Skills for Tightening Fittings (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Has a working knowledge of hydraulic fittings

_____ 2. Knows how to prepare materials for installation

_____ 3. Knows how to use special tools such as flaring and swage equipment

_____ 4. Knows the hazards of handling hydraulic fluids

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____
2. ____
3. ____
4. ____
5. ____

<u>TASK</u>	F	C	D	S	CM
Installing gaskets	_____	_____	_____	_____	_____

Knowledges and Skills for Installing gaskets (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to select the proper materials

_____ 2. Knows how to torque properly

_____ 3. Knows how to use basic math skills such as addition, subtraction, and fractions

_____ 4. Knows how to follow proper Rad protection procedures

_____ 5. Knows how to seal gaskets

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

<u>TASK</u>	F	C	D	S	CM
Changing vee belts on motors	_____	_____	_____	_____	_____

Knowledges and Skills for Changing vee belts (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to use measuring tools

_____ 2. Knows how to use appropriate hand tools

_____ 3. Knows how to make tension adjustments

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____
2. ____
3. ____
4. ____
5. ____

TASK	F	C	D	S	CM
Cleaning and changing filters	_____	_____	_____	_____	_____

Knowledges and Skills for Cleaning and changing filters (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to take equipment out-of-service

_____ 2. Knows how to disassemble and reassemble filter equipment

_____ 3. Knows how to use the proper hand tools

_____ 4. Knows how to follow proper Rad protection procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

TASK	F	C	D	S	CM
Insulating	_____	_____	_____	_____	_____

Knowledges and Skills for Insulating (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to use measuring tools such as rulers and tape

_____ 2. Knows how to select the proper tools

_____ 3. Knows how to mix batch materials

_____ 4. Knows how to follow proper clean-up procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____
2. ____
3. ____
4. ____
5. ____

TASK	F	C	D	S	CM
Replacing pipe hangers	______	______	______	______	______

Knowledges and Skills for Replacing pipe hangers (Please check the space to the left of each item if you also see it as necessary)

______ 1. Has a working knowledge of rigging techniques

______ 2. Knows how to interpret the instructions of Teoh. Staff engineers

______ 3. Knows how to use insulation materials

______ 4. Knows how to obey standard safety procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

TASK	F	C	D	S	CM
Replacing pipe hangers	____	____	____	____	____

Knowledges and Skills for Replacing pipe hangers (Please check the space to the left of each item if you also see it as necessary)

____ 1. Has a working knowledge of rigging techniques

____ 2. Knows how to interpret the instructions of Tech. Staff engineers

____ 3. Knows how to use insulation materials

____ 4. Knows how to obey standard safety procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

TASK	F	C	D	S	CM
Performing rigging operations	_____	_____	_____	_____	_____

Knowledges and Skills for Rigging (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows the basics of load factors such as ratings for slings, etc.

_____ 2. Knows how to give and receive the proper hand signals

_____ 3. Knows how to balance loads

_____ 4. Knows how to use hoists to lift loads

_____ 5. Knows how to tie knots to secure materials

_____ 6. Knows how to block to avoid the movement of materials

_____ 7. Knows how to crib to build support stands

_____ 8. Knows how to wrap to avoid cutting materials

_____ 9. Knows how to obey standard safety procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

TASK	F	C	D	S	CM
Building scaffolding	_____	_____	_____	_____	_____

Knowledges and Skills for Building scaffolding (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to select proper scaffolding materials

_____ 2. Knows how to use simple hand tools

_____ 3. Knows how to assemble and disassemble scaffolding

_____ 4. Knows how to frame and support a scaffold

_____ 5. Knows how to obey the standard rules of safety

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____
2. ____
3. ____
4. ____
5. ____

TASK	F	C	D	S	CM
Grinding	_____	_____	_____	_____	_____

Knowledges and Skills for Grinding (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to operate the grinding machine

_____ 2. Knows how to prepare a grinding wheel

_____ 3. Knows how to change a grinding wheel

_____ 4. Knows how to operate a hand-held grinder

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____
2. ____
3. ____
4. ____
5. ____

TASK	F	C	D	S	CM
Machining	_____	_____	_____	_____	_____

Knowledges and Skills for Machining (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to set-up lathe and drill press operations

_____ 2. Knows how to use basic machine tools accessories

_____ 3. Knows how to use basic measuring tools such as micrometers, calipers, etc.

_____ 4. Knows how to rig equipment when necessary

_____ 5. Knows how to grind tool bits

_____ 6. Knows how to obey standard safety procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____
2. ____
3. ____
4. ____
5. ____

TASK	F	C	D	S	CM
Performing non-code welding	_____	_____	_____	_____	_____

Knowledges and Skills for non-code welding (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Has a working knowledge of electrodes

_____ 2. Knows how to prepare an area before welding

_____ 3. Knows how to use the acetylene cutting torch

_____ 4. Knows how to adjust the proper settings for pressure and amps

_____ 5. Knows how to fabricate materials

_____ 6. Knows how to use drills, grinders, and other power tools

_____ 7. Knows how to use proper measurng tools

_____ 8. Has a working knowledge of rigging techniques

_____ 9. Knows how to wear protective equipment

_____ 10. Knows how to use fire protection equipment

_____ 11. Knows how to obey standard safety procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

TASK	F	C	D	S	CM
Operating the overhead crane	_____	_____	_____	_____	_____

Knowledges and Skills for Operating the overhead crane (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to operate the controls on the crane

_____ 2. Knows how to give and receive the proper hand signals

_____ 3. Knows how to exercise patience during crane operations

_____ 4. Has a working knowledge of load factors

_____ 5. Has a working knowledge of rigging techniques

_____ 6. Knows how to perform preventive maintenance on the crane

_____ 7. Knows how to perform proper equipment inspection

_____ 8. Knows how to obey standard safety procedures

_____ 9. Knows how to operate the crane's safety escape device

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

TASK	F	C	D	S	CM
Operating forklift truck	_____	_____	_____	_____	_____

Knowledges and Skills for Operating forklift truck (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to operate controls on the forklift in a coordinated manner

_____ 2. Has a working knowledge of lift points

_____ 3. Knows how to use the forklift in rigging operations

_____ 4. Knows how to obey standard safety procedures

_____ 5. Knows how to perform preventive maintenance on the forklift

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

<u>TASK</u>	F	C	D	S	CM
Decontaminating equipment and materials	_____	_____	_____	_____	_____

Knowledges and Skills for Decontaminating equipment and materials (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to follow standard procedures for shielding, containing, transporting, and disposing waste materials

_____ 2. Knows how to fabricate a waste container

_____ 3. Knows how to use power and hand tools

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____
2. ____
3. ____
4. ____
5. ____

TASK	F	C	D	S	CM
Sandblasting					

Knowledges and Skills for Sandblasting (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to follow proper Rad protection procedures

_____ 2. Knows how to set-up equipment

_____ 3. Knows how to select the correct abrasives

_____ 4. Knows how to vacuum blast on flat surfaces

_____ 5. Knows proper clean-up procedures for waste disposal

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

<u>TASK</u>	F	C	D	S	CM
Steam cleaning	_____	_____	_____	_____	_____

Knowledges and Skills for Steam cleaning (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to operate steam cleaning equipment

_____ 2. Knows how to use proper cleaning agents

_____ 3. Knows how to clean-up afterwards

_____ 4. Knows how to obey standard safety procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____
2. ____
3. ____
4. ____
5. ____

TASK	F	C	D	S	CM
Assembling crates and wooden boxes	_____	_____	_____	_____	_____

Knowledges and Skills for Assembling crates and wooden boxes (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to use proper hand and power tools

_____ 2. Knows how to layout materials

_____ 3. Knows how to read blueprints

_____ 4. Knows how to use proper measuring tools

_____ 5. Has a working knowledge of rigging techniques

_____ 6. Knows how to load materials into large containers

_____ 7. Knows how to shield and insulate according to procedures

_____ 8. Knows how to follow proper lead protection procedures

_____ 9. Knows how to obey standard safety procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

TASK	F	C	D	S	CM
Repairing auxiliary equipment (e.g. fish baskets, wire cages, traveling screen baskets, etc.	_____	_____	_____	_____	_____

Knowledges and Skills for Repairing auxiliary equipment (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Has a working knowledge of rigging techniques

_____ 2. Knows how to select and use proper tools

_____ 3. Knows how to paint

_____ 4. Knows how to weld

_____ 5. Knows how to use fasteners

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

TASK	F	C	D	S	CM
Performing routine building maintenance and repair work, etc.	_____	_____	_____	_____	_____

Knowledges and Skills for Performing routine building maintenance and repair work (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to perform plumbing on sinks and toilets

_____ 2. Knows how to replace broken windows and perform glazing work

_____ 3. Knows how to replace and repair tiling

_____ 4. Knows how to hang poster boards, blackboards, etc.

_____ 5. Knows how to operate snow plowing equipment

_____ 6. Knows how to select proper cleaning agents

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

TASK	F	C	D	S	CM
Painting	_____	_____	_____	_____	_____

Knowledges and Skills for Painting (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to prepare an area before painting

_____ 2. Knows how to use brush and roller

_____ 3. Knows how to use spray equipment

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

<u>TASK</u>	F	C	D	S	CM
Repairing door locks	_____	_____	_____	_____	_____

Knowledges and Skills for Repairing door locks (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to use basic hand tools

_____ 2. Knows how to disassemble and assemble lock mechanisms

_____ 3. Knows how to read manufacturer's instructions

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____
2. ____
3. ____
4. ____
5. ____

TASK	F	C	D	S	CM
Operating vehicles at the station site	_____	_____	_____	_____	_____

Knowledges and Skills for Operating vehicles at the station site (Please check the space to the left of each item if you also see it as necessary)

_____ 1. Knows how to operate motor vehicles in accordance with the state's licensing rules

_____ 2. Knows how to maintain motor vehicles

_____ 3. Knows how to obey standard safety procedures

Please list any additional knowledges and skills which you see as necessary but are not listed above:

1. ____

2. ____

3. ____

4. ____

5. ____

APPENDIX B

THE RELATIONSHIP BETWEEN COURSE OBJECTIVES AND TEST ITEMS

MODULE: PUMPS

Objective 1:

The trainee will know that energy must be added to a fluid to pump it from one place to another.

Related Test Items:

[✓ T] F 1. Pumping is a process of adding energy to a liquid or to a gas in order to move it from one point to another.

[✓ T] F 2. Some centrifugal pumps can be placed directly in the liquid to be pumped.

Objective 2:

The trainee will know how reciprocating pumps operate.

Related Test Items:

T [✓ F] 4. Relief valves are generally installed on the suction side of the reciprocating pumps.

6. How many cubic feet of liquid would a single action reciprocating pump deliver in 10 minutes if it had a 10" diameter piston 8" stroke, 10 strokes per minute, and was 80% efficient?

29 CUBIC FEET

Objective 3:

The trainee will know how rotary gear pumps operate.

Related Test Items:

[✓ T] F 3. The close clearance between the gears and case of a rotary pump serve to prevent fluid leakage back to the suction side of the pump.

[✓ T] F 9. The external gear pump is the most widely used rotary pump.

Objective 4:

The trainee will know how jet pumps operate.

Related Test Items:

[✓ T] F 5. The pumping action in a jet pump is created by passing a high velocity of gas or fluid through a nozzle in the pump throat.

7. What type of pump operates on the principle that as a fluid gains in velocity when flowing through a restriction, it loses pressure energy?

JET

Objective 5:

The trainee will know how vacuum pumps are used.

Related Test Item:

10. What type of pump is used to lower air pressure to below atmosphere?

VACUUM PUMP

Objectives 2,3:

Related Test Item:

8. Name two types of displacement pumps.

RICIPROCATING ROTARY GEAR

MODULE: VALVES

Objective 1:

The trainee will be able to name three basic valve functions.

Related Test Item:

1. Name three basic valve functions.

START FLOW REGULATE STOP FLOW

Objective 2:

The trainee will know what the term "WSP Rating" means.

Related Test Item:

[✓ T] F 2. The primary rating of a valve, called the WSP ratings, represents the highest steam pressure with which the valve can be safely used.

Objective 3:

The trainee will be familiar with common bonnet designs.

Related Test Items:

T [✓ F] 3. Threaded bonnets are usually used on large, high pressure valves.

[✓ T] F 5. Pressure seal bonnet type valves are used mainly for high pressure systems.

[✓ T] F 6. A lantern type stuffing box would most likely be used on a valve installed in a system where operating pressures are below atmospheric.

Objective 4:

The trainee will be familiar with common valve disks.

Related Test Items: (None)

(Text covers items)

Objective 5:

The trainee will be able to identify three types of valve operators.

Related Test Items:

T [✓ F] 4. Safety valves are also called relief valves.

10. Name three types of valve operators.

PNEUMATIC HYDRAULIC MOTOR OPERATED

Objective 6:

The trainee will know which valves provide a more streamlined flow.

Related Test Items:

8. Which type of glove valve disk would be used to make fine adjustments of flow?

   NEEDLE OR FLOW CONTROL DISK

9. The path of flow is more streamlined in a GATE valve.

Objective 7:

The trainee will be familiar with common types of valves and how they operate.

Related Test Item:

7. To open or close a plug valve, it must be turned:

   A ½ revolution
   [✓ B] ¼ revolution
   C 1 revolution

MODULE: PIPING

Objective 1:

The trainee will know how pipe is measured.

Related Test Items:

1. Compared to standard pipe, extra strong pipe of the same nominal size has

   A SMALLER INSIDE DIAMETER

2. American Standard taper for pipe threads is 3/4" per foot.

Objective 2:

The trainee will know that American Standard taper is 3/4" per foot.

Related Test Items: (None)

(Text covers item)

Objective 3:

The trainee will know the purpose of backing rings.

Related Test Items: (None)

(Text covers item)

Objective 4:

The trainee will know the difference between "end-to-end" and "center-to-center" pipe measurements.

Related Test Item:

T [✓ F] 1. The "end-to-end" measurement of a pipe is always longer than "center-to-center."

Objective 5:

The trainee will know how to calculate travel for a 45 offset.

Related Test Item:

7. If a 45 offset arrangement has a "set" of 12", the "travel" = 16.968

Objective 6:

The trainee will know how to calculate the length of pipe in a rolling offset.

Related Test Item:

8. You can determine the "travel" of a rolling offset if you know the run, set, and the ROLL

Objective 7:

The trainee will know the difference between a "Y" strainer and an "S" strainer.

Related Test Item:

[✓ T] F 10. An "S" type strainer has more screen area than a "Y" type.

NOTE: Test items not included in objectives.

The test items are covered in the text.

3. Backing rings are sometimes used when WELDING a pipe.

9. A counterpoise pipe hanger uses a SPRING to keep support constant.

MODULE 3: CENTRIFUGAL PUMPS

Objective 1:

The trainee will know how a centrifugal pump operates.

Related Test Items:

4. The inboard bearing of a horizontal split-case pump usually carries RADIAL LOAD

6. The impeller of a centrifugal pump operates by FLINGING FLUIDS OUTWARD

7. In a Kingsbury Thrust Bearing, thrust is actually carried by FILM OF OIL

Objective 2:

The trainee will be able to identify a

Horizontal split-case pump
Vertical pump

Related Test Item:

10. Which type of centrifugal pump has a horizontal shaft with an impeller near the middle? HORIZONTAL SPLIT-CASE PUMP

Objective 3:

The trainee will know the purpose of a volute type pump casing.

Related Test Item: (None)

(Text covers item)

Objective 4:

The trainee will know the function of the lantern ring.

Related Test Items: (None)

(Text covers item)

Objective 5:

The trainee will know the function of mechanical seals.

Related Test Item:

8. Mechanical seals are used in the stuffing box instead of PACKING

Objective 6:

The trainee will know that multi-stage pumps produce higher discharge pressures.

Related Test Items:

[✓ T] F 3. Two pumps connected in series can produce twice the total head of one pump.

9. Barrel casings are used where the PRESSURE and TEMPERATURE are high.

Objective 7:

The trainee will know the purpose of a double volute casing.

Related Test Item:

2. The advantage of a double volute pump casing is BETTER BALANCE

Objective 8:

The trainee will know the purpose of recirculation lines on pumps.

Related Test Items: (None)

(Text covers item)

Objective 9:

The trainee will know the purpose of wear rings.

Related Test Item:

5. Besides decreasing wear on impellers and casing, wear rings also help limit RECIRCULATION LOSS

Objective 10:

The trainee will be able to determine the direction of impeller rotation by inspecting impeller vanes.

Related Test Item:

1. Indicate the proper direction of rotation of the impeller. COUNTER-CLOCKWISE

MODULE 6: MECHANICAL SEALS

Objective 1:

The trainee will know the difference between a mechanical seal and packing.

Related Test Item:

[✓ T] F 8. In most cases, mechanical seals can directly replace packing with no modifications to the pump.

Objective 2:

The trainee will know how mechanical seals work.

Related Test Items:

T [✓ F] 7. A balanced mechanical seal exerts more force at the sealing edge than an unbalanced seal.

[✓ T] F 9. More heat is generated by unbalanced seals than balanced ones.

Objective 3:

The trainee will know the advantage of mechanical seals.

Related Test Items:

1. Name one advantage of mechanical seals over packing. ZERO LEAKAGE

Objective 4:

The trainee will know the major cause of mechanical seal failure.

Related Test Items:

5. Name two major causes of mechanical seal failure.
HIGH TEMPERATURE POOR INSTALLATION

T [✓ F] 10. Excessive shaft runout is compensated for by a balanced mechanical seal.

Objective 5:

The trainee will know the basic steps of installing a mechanical seal.

Related Test Items:

3. If a mechanical seal is not installed at its correct operating length, the LEADING/FACE may not be correct.

T [✓ F] 4. The smoothness of a lapped sealing edge of mechanical seal can be checked with a dial indicator.

6. When installing a mechanical seal, a line is scribed on the packing sleeve even with
THE END OF THE STUFFING BOX

APPENDIX C

INSTRUCTIONAL OBSERVATION REPORT

Instructor ____________________

Location ____________________

Date ____________________

Number of Trainees ____________________

	Superior/Outstanding 5	Good 4	Adequate 3	Weak 2	Very Poor 1	Unable to Evaluate 0
1. PLANNING AND PREPARATION						
A. Identifies a continuum of long and short term course objectives.	5	4	3	2	1	0
B. Prepares and maintains written plans with appropriate objectives.	5	4	3	2	1	0
C. Plans individual and group activities (i.e., field trips, role playing, class discussion, movies, slides, records, interaction, etc.)	5	4	3	2	1	0
D. Selects appropriate learning strategies from available sources: Texts, supplements, AV materials, etc.	5	4	3	2	1	0
E. Evaluates his objectives.	5	4	3	2	1	0
F. Modifies lesson plans as necessary.	5	4	3	2	1	0
2. ORGANIZATION OF TRAINEES AND CLASSROOM MANAGEMENT						
Professional Tasks						
A. Provides an environment in which trainees learn and interact.	5	4	3	2	1	0
B. Provides an environment in which the trainee feels emotionally and physically secure.	5	4	3	2	1	0

	Superior/Outstanding	Good	Adequate	Very Poor	Unable to Evaluate	
	5	4	3	2	1	0
Procedural Tasks						
A. Follows routine station/company procedures.	5	4	3	2	1	0
B. Accepts and carries out routine duties and assignments.	5	4	3	2	1	0
C. Maintains appropriate trainee records and submits required reports within designated time limits.	5	4	3	2	1	0
D. Develops and maintains appropriate classroom materials, displays and equipment.	5	4	3	2	1	0

3. INSTRUCTION AND INTERACTION

Instruction

A. Chooses activities and methods which best meet predetermined objectives.	5	4	3	2	1	0
B. Uses materials economically.	5	4	3	2	1	0
C. Is aware of, and uses industry and government resources when available and applicable	5	4	3	2	1	0
D. Encourages full trainee participation in the learning experience.	5	4	3	2	1	0
E. Encourages trainee in both affective and cognitive domains.	5	4	3	2	1	0
F. Encourages analytical and critical thinking.	5	4	3	2	1	0
G. Teaches desirable work habits and study skills.	5	4	3	2	1	0

	Superior/Outstanding 5	Good 4	Adequate 3	Weak 2	Very Poor 1	Unable to Evaluate 0
H. Provides opportunities for individual achievement.	5	4	3	2	1	0
I. Executes plans.	5	4	3	2	1	0
J. Handles trainee questions confidently and smoothly.	5	4	3	2	1	0
<u>Interaction</u>						
A. Explains objectives fully to trainee so that they know what is expected from them in the learning situation.	5	4	3	2	1	0
B. Creates an atmosphere where trainees feel free to express their views while encouraging respect for the rights, opinions, property, and contribution of others.	5	4	3	2	1	0
C. Creates an atmosphere in which trainees perceive that the instructor cares about what and how they learn.	5	4	3	2	1	0
D. Promotes self-awareness and self-respect.	5	4	3	2	1	0
E. Encourages trainees to work to the best of their abilities and to take pride in their achievements.	5	4	3	2	1	0
F. Is sensitive to, and adjusts, as necessary, to differences among trainees and considers the overall well-being of the individual.	5	4	3	2	1	0
G. Is available for individual consultation at a mutually agreed upon time.	5	4	3	2	1	0

		Superior/Outstanding 5	Good 4	Adequate 3	Weak 2	Very Poor 1	Unable to Evaluate 0
H.	Keeps in confidence information that has been obtained in the course of professional service, unless disclosure serves professional purposes or is required by law.	5	4	3	2	1	0
I.	Develops classroom discipline that is sufficient for learning to take place but flexible enough not to be stifling.	5	4	3	2	1	0
J.	Uses relevant examples to reinforce concepts.	5	4	3	2	1	0
K.	Attempts to gain the attention and respect of trainees.	5	4	3	2	1	0
L.	Is consistent in his/her expectations of and reactions to trainee's behavior.	5	4	3	2	1	0
M.	Demonstrates an acceptance of the trainee's development from dependence toward independence.	5	4	3	2	1	0
N.	Calmly manages his/her own discipline recognizing that extreme situations may require administrative services.	5	4	3	2	1	0
4.	<u>ASSESSMENT</u>						
A.	Uses a variety of evaluative techniques for diagnostic purposes and/or placement.	5	4	3	2	1	0
B.	Interprets the results of evaluative instruments and techniques.	5	4	3	2	1	0
C.	Establishes and informs trainees of the basis of assessment.	5	4	3	2	1	0

	Superior/Outstanding 5	Good 4	Adequate 3	Weak 2	Very Poor 1	Unable to Evaluate 0
D. Periodically assesses trainee accomplishment of objectives.	5	4	3	2	1	0
E. Reviews test results and evaluative results with trainees, where appropriate.	5	4	3	2	1	0
F. Encourages trainee self-evalution.	5	4	3	2	1	0
5. COMPENTENCIES AND PROFESSIONAL DEVELOPMENT						
A. Demonstrates knowledge and application of subject matter.	5	4	3	2	1	0
B. Keeps abreast of developments in techniques, philosophy, and content in the professional literature relating to teaching practice and subject areas.	5	4	3	2	1	0
C. Takes advantage of opportunities for professional growth as courage, in-service training, and conference in his/her area of specialization and competency.	5	4	3	2	1	0
D. Makes use of constructive criticism.	5	4	3	2	1	0
E. Sets realistic goals for self, based on a clear perception of his/her limitations and capabilities and the reality of his/her situation.	5	4	3	2	1	0
F. Makes use of trainee reactions as valid data for the evaluation of his/her teaching effectiveness.	5	4	3	2	1	0
G. Demonstrates self-control.	5	4	3	2	1	0
H. Demonstrates self-confidence.	5	4	3	2	1	0

		Superior/Outstanding 5	Good 4	Adequate 3	Weak 2	Very Poor 1	Unable to Evaluate 0
I.	Questions the system constructively when believed necessary.	5	4	3	2	1	0
J.	Identifies any factors that may have interfered with teaching effectiveness.	5	4	3	2	1	0
K.	Shows interest in station/company activities.	5	4	3	2	1	0
L.	Gives evidence of implementing administrative procedures.	5	4	3	2	1	0
M.	Communicates effectively.	5	4	3	2	1	0
N.	Maintains regular and prompt attendance habits.	5	4	3	2	1	0

6. HUMAN RELATIONSHIPS

A.	Cooperates with co-workers by sharing ideas and methods of instruction.	5	4	3	2	1	0
B.	Exhibits professional and ethical behavior toward fellow teachers and co-workers.	5	4	3	2	1	0
C.	Contributes to committees, training staff meetings.	5	4	3	2	1	0
D.	Seeks assistance, advice, and guidance, as necessary, from colleagues and/or specialists.	5	4	3	2	1	0
E.	Provides assistance, advice, and guidance as necessary, for colleagues.	5	4	3	2	1	0

APPENDIX D

t-TEST FOR RELATED MEASURES FOR PRE- AND POST-TEST SCORES

Test Results Statistic

Used to determine the significance of a difference between two correlated means. It is most commonly used when two scores are recorded for the same individuals. For instance, test scores might be taken at the beginning and end of a special training program to determine if there has been any improvement in test scores.

Formula: $$t = \frac{\bar{X} - \bar{Y}}{\sqrt{\dfrac{\sum D^2 - \dfrac{(\sum D)^2}{N}}{N(N-1)}}}$$

Where D = difference score between each X and Y pair

N = number of pairs of scores

Source: J. L. Bruning, B. L. Kintz, Computational Handbook of Statistics, 1977, Scott Foresman, pp. 13-16.

Step 1

Pair scores, pre-test, and post-test scores for each individual must be in the same relative position.

Group 1

	Pre-Test Score	Post-Test Score	Difference
S_1	42	93	51
S_2	42	90	48
S_3	58	88	30
S_4	40	85	45

Step 2

Obtain the difference between each pair of scores.

Step 3

Square all the difference scores recorded in Step 2, and these square values.

$(51)^2 = (48)^2 + (30)^2 + (45)^2 \ldots = 7830$

Step 4

Obtain the algebraic sum of the difference scores obtained in Step 2. Square this value, and divide by the number of difference scores recorded.

(51) + (48) + (45) . . . = 174

$\frac{1742}{4} = \frac{30,276}{4} = 7569$

Step 5

Subtract the value obtained in Step 4 from the sum in Step 3.

7830 - 7569 = 261

Step 6

Divide the value obtained in Step 5 by N-1. (In the example, this is 4-1=3, since N refers to pairs of scores.)

$\frac{261}{3} = 87$

Step 7

Take the square root of the value obtained in Step 6.

87 = 9.33

Step 8

Divide the value of Step 7 by N . (In the example, 4 = 2.)

$\frac{9.33}{2} = 4.66$

Step 9

Obtain the mean score of each of the two tests, pre and post, add all the scores in each grouping and divide each sum by the number of scores added to obtain it.

42 + 42 + 58 + 40 = Sum of Pre-test Scores

93 + 90 + 88 + 85 = Sum of Post-test Scores

$\frac{182}{4}$ = 45.5 = Mean for Pre-test Scores

$\underline{356}$ = 89 = Mean for Post-test Scores

Step 10

Subtract the mean for Pre-test scores from mean for Post-test scores.

45.5 - 89 = 43.5

Step 11

Divide the value obtained in Step 10 by the value obtained in Step 8. This yields the t value.

$t = \frac{43.5}{4.66} = 9.33$

Step 12

To determine whether the t value is significant, the degrees of freedom (df) must first be obtained. For the t related measures, the df = N-1 where N is the number of pairs of scores. In the example, N-1 = 3. From the t tables (Appendix D), we find that the t value that is significant between the .01 and .001 levels of significance.

Since the obtained t value is larger than 5.841 at the .01 level of significance it is concluded that the training program improved the test scores for each individual in the groups studied.

t Statistic

	Alpha level of significance for directional (one-tailed) tests					
df	.25	.05	.025	.01	.005	.0005
	Alpha level of significance for nondirectional (two-tailed) tests					
	.50	.10	.05	.02	.01	.001
1	1.000	6.314	12.706	31.821	63.657	636.619
2	.816	2.920	4.303	6.965	9.925	31.598
3	.765	2.353	3.182	4.541	5.841	12.941
4	.741	2.132	2.776	3.747	4.604	8.610
5	.727	2.015	2.571	3.365	4.032	6.859
6	.718	1.943	2.447	3.143	3.707	5.959
7	.711	1.895	2.365	2.998	3.499	5.405
8	.706	1.860	2.306	2.896	3.355	5.041
9	.703	1.833	2.262	2.821	3.250	4.781
10	.700	1.812	2.228	2.764	3.169	4.587
11	.697	1,796	2.201	2.718	3.106	4.437
12	.695	1.782	2.179	2.681	3.055	4.318
13	.694	1.771	2.160	2.650	3.012	4.221
14	.692	1.761	2.145	2.624	2.977	4.140
15	.691	1.753	2.131	2.602	2.947	4.073
16	.690	1.746	2.120	2.583	2.921	4.015
17	.689	1.740	2.110	2.567	2.898	3.965
18	.688	1.734	2.101	2.552	2.878	3.922
19	.688	1.729	2.093	2.539	2.861	3.883
20	.687	1,725	2.086	2.528	2,845	3.850
21	.686	1.721	2.080	2.518	2.831	3.819
22	.686	1.717	2.074	2.508	2.819	3.792
23	.685	1.714	2.069	2.500	2.807	3.767
24	.685	1.711	2.064	2.492	2.797	3.745
25	.684	1.708	2.060	2.485	2.787	3.725
26	.684	1.706	2.056	2.479	2.779	3.707
27	.684	1.703	2.052	2.473	2.771	3.690
28	.683	1.701	2.048	2.467	2.763	3.674
29	.683	1.699	2.045	2.462	2.756	3.659
30	.683	1.697	2.042	2.457	2.750	3.646

t Statistic

	Alpha level of significance for directional (one-tailed) tests					
df	.25	.05	.025	.01	.005	.0005
	Alpha level of significance for nondirectional (two-tailed) tests					
	.50	.10	.05	.02	.01	.001
40	.681	1.684	2.021	2.423	2.704	3.551
60	.679	1.671	2.000	2.390	2.660	3.460
120	.677	1.658	1.980	2.358	2.617	3.373
	.674	1.645	1.960	2.326	2.576	3.291

Source: Appendix B is taken from Table III of Fisher & Yates: Statistical Tables for Biological, Agricultural and Medical Research, published by Oliver & Boyd Ltd., Deinburgh, and by permission of the authors and publishers. This abridgment is reproduced from John G. Peatman, Introduction to Applied Statistics. New York, New York: Harper & Row, Publishers, 1953. Reprinted by permission.

GROUP 1 N=7

SUBJECT: Pumps

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	42	93	52
S_2	42	90	48
S_3	58	88	30
S_4	40	85	45
S_5	42	88	46
S_6	50	91	41
S_7	63	98	35
	337	633	296

*NOTE: S_8 (1) Student was absent for Pre-Test on Pump Module. Cast out (S_8).

t = 14.94

P = .001

GROUP II N=5

SUBJECT: Pumps

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	53	88	35
S_2	38	88	50
S_3	13	70	57
S_4	60	85	25
S_5	43	78	35
	207	409	202

t = 7.03

P = .001

GROUP III N=7

SUBJECT: Pumps

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	63	97	34
S_2	63	79	16
S_3	50	95	45
S_4	50	90	40
S_5	63	94	31
S_6	45	90	45
S_7	55	95	40
	389	640	251

$t = 9.31$

$P = .001$

GROUP IV N=8

SUBJECT: Pumps

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	70	90	20
S_2	40	94	54
S_3	40	90	50
S_4	47	100	53
S_5	57	90	33
S_6	57	87	30
S_7	37	100	63
S_8	30	100	70
	378	751	373

$t = 5.83$

$P = .001$

GROUP I N=8

SUBJECT: Valves

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	70	90	20
S_2	45	85	40
S_3	60	85	25
S_4	60	95	35
S_5	55	95	40
S_6	65	80	15
S_7	65	90	25
S_8	45	80	35
	465	700	235

t = 8.82

P = .001

GROUP II N=5

SUBJECT: Valves

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	65	95	30
S_2	55	90	35
S_3	60	95	35
S_4	50	90	40
S_5	50	85	35
	280	455	175

t = 22.15

P = .001

GROUP III N=7

SUBJECT: Valves

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	75	85	10
S_2	75	95	20
S_3	65	95	30
S_4	50	100	50
S_5	60	95	35
S_6	80	100	20
S_7	55	90	35
	385	660	200

t = 7.92

P = .001

GROUP IV N=8

SUBJECT: Valves

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	20	90	70
S_2	20	90	70
S_3	0	70	70
S_4	40	80	40
S_5	20	90	70
S_6	0	80	80
S_7	40	100	60
S_8	40	100	60
	180	700	520

$t = 15.40$

$P = .001$

GROUP I N=8

SUBJECT: Piping

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	20	95	75
S_2	35	95	60
S_3	25	80	55
S_4	30	100	70
S_5	30	100	70
S_6	25	85	60
S_7	25	90	65
S_8	15	70	55
	205	715	510

t = 15.40

P = .001

GROUP II N=5

SUBJECT: Piping

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	50	80	30
S_2	35	84	49
S_3	50	85	35
S_4	55	100	45
S_5	55	85	30
	245	434	189

$t = 9.67$

$P = .001$

GROUP III N=7

SUBJECT: Piping

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	55	90	35
S_2	65	100	35
S_3	55	100	45
S_4	65	90	25
S_5	45	95	50
S_6	65	90	25
S_7	52	70	18
	402	635	233

$t = 7.67$

$P = .001$

GROUP IV N=8

SUBJECT: Piping

	Pre-Test No Formal Instruction	Post-Test Following Formal Instruction	Difference
S_1	80	90	10
S_2	40	90	50
S_3	35	85	50
S_4	60	85	25
S_5	60	80	20
S_6	60	80	20
S_7	40	75	35
S_8	75	90	15
	450	675	225

$t = 5.19$

$P = .001$

APPROVAL SHEET

The dissertation submitted by John Joseph Gammuto has been read and approved by the following committee:

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The final copies have been examined by the director of the dissertation and the signature which appears below verifies that any necessary changes have been incorporated and that the dissertation is now given final approval by the Committee with reference to content and form.

The dissertation is therefore accepted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

Dec 3, 1981
Date

Director's Signature